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ORIGINAL ARTICLES.

I.—The Chiltern Wind Gaps.

By J. W. Gregory, D.Sc., F.R.S.

THE Geological History of the Thames is still the subject of conflicting hypotheses. Mr. F. W. Harmer (1907)[1] has drawn a very interesting parallel between the basin of the Middle Thames around Oxford and the Vale of Pickering in Yorkshire. The latter, as is well known from Professor Kendall's paper (1902),[2] was occupied by a glacial lake which was due to the Derwent River having had its outlet to the sea south of Scarborough closed by a dam of ice; the water rose in this lake until it overflowed at a gap near Malton; the river thus formed cut a gorge through which the drainage from the Vale of Pickering flows south-westward into the Yorkshire Ouse, and reaches the sea through the Humber. According to Mr. Harmer the Upper Thames originally discharged north-eastward through the Fens into the Wash; this outlet was blocked by the ice; the waters of the Upper Thames collected as a lake, which was discharged by overflow channels cut through the Chiltern Hills, and as the lake-level fell the discharge was maintained only through the Goring Gap at the south-western end of the Chiltern Hills. This view advances a different explanation of the Chiltern wind gaps than that advocated in a paper in 1894,[3] and is opposed to the theory of the evolution of English rivers adopted by Professor W. M. Davis in 1895.[4]

The analogy drawn by Mr. Harmer between the basins of the Upper Thames and the Vale of Pickering is very attractive; but the striking difference between the arguments for Lake Pickering and for Lake Oxford is, that for the former there is abundant positive evidence, while for Lake Oxford there is no such direct evidence. Professor Kendall has demonstrated the changes in the course of the Derwent and the former existence of Lake Pickering by convincing evidence. That the Derwent formerly reached the sea through the great valley south of Scarborough appears so obvious as to be almost indisputable. The former existence of Lake Pickering is shown by the form of the basin and the abundant deposits on its floor; and the margins of the old lake are indicated by well-developed lake beaches and deltas. If Mr. Harmer's Lake Oxford had been in existence at about the same period as Lake Pickering—and they are both assigned to the period at the close of the Boulder-clay—we

might expect corresponding evidence for both lakes. On the contrary, the assumed outlet of the Thames to the Wash is very doubtful. The lake deposits on the floor of this basin are insignificant, and can be explained by local pools which would not have answered the requirements of Lake Oxford; and though the Brightwell gravels to the north of the Goring Gap are referred to by Mr. Harmer as possibly "littoral accumulations of a lake" (1907, No. 1, p. 503), there are no clear remains of lake terraces or deltas.

The strongest argument for Lake Oxford is the existence of the gorge of the Thames at Goring and of the wind gaps through the Chilterns; but re-examination of the evidence confirms my original impression that these gaps were cut by pre-Glacial rivers. They present difficulties, which appear to me insuperable, to the theory that they were cut by the overflow from a glacial lake. The second figure in my paper of 1894 (No. 3, p. 106) shows that these gaps stand at very different levels. The floor of the Hampden Gap is at about the height of 700 feet, and the escarpment beside it rises over 800 feet. The deepest of the gaps, that at Tring, has been cut down to the level of 430 feet. The Hampden Gap could only have been made by a lake which was at the level of more than 800 feet above the sea. No such lake could have existed unless the broad opening between the Berkshire Downs and the Chiltern Hills, on the floor of which the Goring Gap has been incised, was post-Glacial. The existence of Triassic drift down to the level of below 300 feet above Wallingford and near Pangbourne shows that the Thames Valley at Goring had been cut down to below 300 feet above sea-level in pre-Glacial times.[5]

The top of the gorge at Goring is at about the level of 450 feet, and even if the whole gorge below that level had been cut after the existence of the assumed Lake Oxford, the water in that lake could not have stood much above that level. The overflow from the lake might have deepened the gaps at Tring, Wendover, and Saunderton, which have been cut down respectively to 430, 503, and 461 feet; but even these three deep gaps could only have been initiated by the lake if its surface had stood over 800 feet above the sea; and that Lake Oxford could ever have stood at that level seems impossible. If these gaps had been deepened from about 540 feet, which seems to me the highest possible level of the lake, then they would have been in existence before Lake Oxford, which would explain only the deepening and not the origin of the wind gaps. The conclusion that the Chiltern gaps were cut by rivers when the Chalk extended farther to the north-west, and are a series of pre-Glacial valleys of which the rivers have been beheaded by the Thame, still seems to me the most probable explanation.

Mr. Harmer's objection to this origin of the wind gaps is based on their modern appearance and their occurrence as more or less rectilinear channels (1907, p. 503); but there seems no very marked difference between them and some of the valleys in the Wealden Downs, which would appear to be certainly pre-Glacial. It is important to remember in connexion with the form of the valleys that in all probability the Chiltern Hills were never covered with ice.

The ice which deposited the boulder-clay extended over the lowland on both sides of the north-eastern end of the Chiltern Hills, but did not cover them or reach the main part of the range. Mr. Harmer's map (1907, pl. xxxiv) shows clearly the relation of the Chiltern Hills to the boulder-clay, and the only evidence for the glaciation of the Chilterns is that based upon the plateau gravels, which, as I maintained in 1894, are non-glacial and pre-Glacial.

The view that these high-level gravels are of glacial origin has, however, been adopted by Mr. T. I. Pocock in the memoir on *The Geology of the Country around Oxford*.[6] He has clearly restated the arguments for the glacial origin of the beds; and he considers that all the Oxford district was covered by ice, and that the country has been lowered during Pleistocene times, mainly by glacial denudation, to the extent in places of 450 feet. The evidence advanced by Mr. Pocock seems inconclusive, and he quotes the late H. B. Woodward, who was superintending the survey of the district, as "strongly of opinion that none of the plateau drifts can be regarded as the immediate product of land ice, in the sense of being boulder-clay; but that there are remnants of 'washed drift' of Glacial age" (No. 6, p. 103, footnote). The distinction between glacial and non-glacial gravels afforded by the presence of Jurassic material is, of course, not available in the Upper Thames Valley; but other evidence of glacial action should be forthcoming. I go further than H. B. Woodward, by doubting whether there is any reason to regard the plateau drifts as even the wash of glacial beds. Mr. Osborne White (No. 7) and Dr. Salter (No. 8, p. 286) agree as to the fluviatile origin of these plateau drifts. Mr. White, for example, concludes (No. 7, p. 173) that "it seems almost impossible to resist the conclusion that, despite the great elevation it attains above the beds of the neighbouring streams, this gravel owes its existence to fluviatile agency, operating along the same general lines of drainage as those in existence at the present day". Mr. White adds (No. 7, p. 173), "There is no reason to think that the part played by ice in the formation of this gravel was ever more than a subordinate one."

It may be said that possibly the Chiltern wind gaps were pre-Glacial while the gorge at Goring was glacial. Mr. Harmer, however, lays stress on the probability that the wind gaps and the Goring gorge were due to the same cause, and therein I fully agree with him. Hence the theory suggested by Sir Joseph Prestwich, that the Upper Thames and Thame once discharged north-eastward into the Wash, appears improbable, and the Chiltern wind gaps may be best explained as the remains of pre-Glacial valleys, which were excavated by rivers now beheaded by the Thame.

[1] F. W. Harmer, "The Origin of certain Cañon-like Valleys": Quart. Journ. Geol. Soc., vol. lxiii, pp. 470–513, pls. xxxi–v, 1907.

[2] P. F. Kendall, "Glacier-Lakes in the Cleveland Hills": Quart. Journ. Geol. Soc., vol. lviii, pp. 471–571, pls. xx–viii, 1902.

[3] J. W. Gregory, "The Evolution of the Thames": Nat. Sci., vol. v, pp. 97–108, 1894.

[4] W. M. Davis, "The Development of certain English Rivers": Geog. Journ., vol. v, pp. 127–46, 1895.

[5] Mr. Osborne White is also of the opinion that the excavation of the Goring Gap was begun in long pre-Glacial times.

[6] T. I. Pocock, *The Geology of the Country around Oxford*, Mem. Geol. Surv. England and Wales, 1908, pp. vi, 142.

[7] H. J. Osborne White, "On the Origin of the High-level Gravel with Triassic Debris adjoining the Valley of the Upper Thames": Proc. Geol. Assoc., vol. xv, pp. 157–74, pl. vii, 1899. The view that the clay with flints on the Buckinghamshire hills is of glacial origin has been maintained by Sherlock & Noble (Quart. Journ. Geol. Soc., vol. lxviii, pp. 199–212, pls. xii–xiv, 1912). In the discussion on this paper the authors' views were generally rejected.

[8] A. E. Salter, "Pebbly and other Gravels in Southern England": Proc. Geol. Assoc., vol. xv, pp. 264–86, 1899.

II.—Notes on the Petrology of a portion of the North Kalgoorlie Field.

By R. A. Farquharson, M.A. (Oxon.), M.Sc., F.G.S.,
Petrologist to the Mines Department of Western Australia.

(PLATES VI AND VII.)

(*Concluded from the March Number, p. 114.*)

From the foregoing analyses there is little doubt that the rock is a hornblende-quartz-keratophyre. The term porphyrite, however, has been adopted in the mapping for convenience. It is worthy of note that a very similar rock, though greenish in colour, has been already described from Kanowna by the writer.[1] In the latter, silica amounted to more than 71 per cent, while soda reached 7·85 per cent; potash was again absent.

12237, G.M.L. 4458 E., Hyman North.[2]

The rock is finer in texture than the preceding one, but has no remains of hornblende phenocrysts, and the ground-mass is of very fine grain, and is intermixed with fine flakes of muscovite. A few of the felspar phenocrysts are cracked. There are a few aggregates of a yellow chlorite, some brown-red grains and dust of iron-ore. The 'matrix' of 12331B, G.M.L. 4458 E., Hyman North, is similar to 12237, though the former shows unmistakable evidence of shearing action, not only in the parallel orientation of sericite fibres and the presence of brownish-yellow flakes or spots of chlorite, but also in a 'lined' or 'grated' appearance in section, due beyond doubt to the sliding of one portion of the mass over another.

12316 (about 5½ chains north-west of south corner of G.M.L. 4161 E.) is very similar in section to the previous specimens, but the felspar both in the phenocrysts and in the ground-mass is almost all altered to sericitic aggregates, amongst which the quartz plates are easily visible.

12368, 120 ft. level G.M.L. 4406 E., Hyman, is distinctly porphyritic with ferruginous outlines of former hornblende.

[1] Bulletin No. 47 G.S.W.A., Petrological Notes, p. 71.

[2] M.C. = a weathered brownish rock. S. = minerals: felspar, quartz, chlorite, sericite, and iron-ore.

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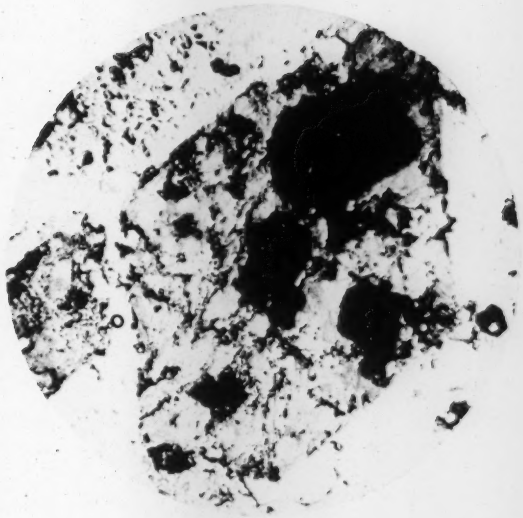

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Rock-sections, Kalgoorlie.

To illustrate Mr. Farquharson's paper (see March Number, p. 113).

In No. 11106, square, columnar, and other shapes of a turbid, indistinctly twinned felspar, together with irregular patches of calcite, appear in a ground-mass that consists of small square and lath-shaped felspars, minute granules apparently of quartz, numerous round grains of pyrites, and small scales of green chlorite. The felspar, both of the phenocrysts and of the ground-mass, is more or less kaolinized, so that determination of the species is difficult. It is highly probable, however, that the rock is another variety of the porphyrite with felspar phenocrysts.

10433 closely resembles 12331A and 12368. There are large kaolinized phenocrysts of twinned albite in various forms in a ground-mass of small felspar squares and laths, without any 'flow' structure, and small interstitial plates of quartz. There are also large green chloritic aggregates without definite shape enclosing talcose fibres, and usually brown from iron oxide. These, no doubt, represent the hornblende phenocrysts noticeable in some other sections. One or two large plates of clear quartz are visible in places, and there are occasional patches of brown-stained carbonate.

12321 differs from the above only in having a larger development of granular calcite and a tendency towards felted structure in the laths of the ground-mass. A considerable amount of sericitic mica also is distributed over the slide.

In 12232 large deep-green chloritized hornblende columns and prisms make their appearance, often stained, however, by iron oxide. They are disposed in a fine-grained ground-mass which consists of more or less twinned felspar laths, and which closely resembles the ground-mass of 12376. Felspar phenocrysts are not observable in this slide.

2937 and 10434. These are blackish rocks with white, somewhat lenticular spots of a white carbonate, which, as it gives an effervescence with cold dilute H Cl, though a feeble one, is at least in part of calcite. In section green chloritic patches and granular carbonate in rounded and columnar forms, as well as in small grains, stand out of a ground-mass of minute lath-shaped and small short columnar crystals of a twinned and turbid felspar. The carbonate areas appear in places mixed with chlorite and quartz, some, mainly chlorite, have almost exactly the form of cross-sections and elongated forms of hornblende crystals (see especially 2937). It is possible, also, that some of the forms, though they show no remains of twinning, represent original felspar phenocrysts. Numerous small black grains of magnetite are scattered through the mass.

The rocks are difficult to place, but the character of the phenocrysts and the nature of the ground-mass have led to their being classed as hornblende porphyrites. A slight tendency to the drawing out of the white spots in a parallel direction is observable in the hand-specimen, a fact presupposing some shearing action on the rock-mass.

12311 is a hard reddish rock with a few dark-green specks. In section there are numerous square and columnar phenocrysts more or less decomposed with the production of kaolin and sericite. These stand out of a ground-mass consisting of a few felspar forms, granular

quartz, granular patches of an iron-stained carbonate, some grains of magnetite, and a few patches of green scaly chlorite. One or two larger plates of quartz are to be observed, but phenocrysts of the mineral are conspicuously absent. The species of felspar present was indeterminable owing to the alteration the mineral has undergone.

The rock may be either a quartz-porphyry, with quartz wanting among the phenocrysts, or an altered specimen of keratophyre.

(*b*) *The Non-Porphyritic Type.*

12231. In hand-specimens, the same in appearance as the other brown specimens. In section the rock is seen to be devoid of felspar phenocrysts, and to consist of a plexus of trimmed laths of felspar, among which quartz is very hard to identify. In the ground-mass are several long, thin, acicular as well as rectangular crystals, yellow in colour, which are doubtless chloritized remains of hornblende forms. Here and there are pieces of tourmaline without definite shape, with a dichroism from deep green to pale violet or lavender.

12233 is in a hand-specimen a light-grey, compact, fine-grained rock with a brown crust. The section is composed entirely of irregularly outlined laths of felspar of considerable size, some interstitial quartz, and some aggregates and scattered scales of greenish pleochroic chlorite with grains and squares of magnetite. Phenocrysts are absent, though some of the laths attain unusual size (Pl. VII, Fig. 3). Twinning is pronounced, and measurements of extinction angles indicate albite or oligoclase-albite. The irregular nature of the outline of the laths is a noteworthy feature.

B. Rocks of Gabbroid or Doleritic Origin.

The rocks of this group are either light-grey with green spots and rather hard, e.g. 12324, or dark-green, soft, and with minute quartz crystals, e.g. 12379. As stated previously, the distinctive characters of the group are few, but generally there are clear outlines of long columnar twinned felspars, and in two specimens at least, 12324 and 12322, a kind of coarse ophitic structure.

12324. Minerals observed: hornblende, felspar, quartz, zoisite, epidote, chlorite, apatite, iron-ore.

The section consists of large ragged plates and flakes, of a pale, almost colourless hornblende that is sometimes partially chloritized, disposed amongst numerous completely turbid rectangular and columnar crystals of felspar, with idiomorphic outline. The turbidity is seen with high powers to be due to a granular mass of zoisite, epidote, and occasionally clear quartz, and is consequently to be attributed to saussuritization. Between the felspar crystals there is frequently some clear interstitial quartz that is, without doubt, original. Long needles of apatite occasionally make their appearance, and besides forms of leucoxene there are grains of ilmenite surrounded by that mineral.

The idiomorphic nature of the felspars and the platy character of the hornblende suggest a sub-ophitic structure. The rock is an amphibolized and partially saussuritized quartz dolerite.

12322 differs from 12324 only in a greater development of felspar forms, and a smaller development of the ferro-magnesian and quartz.

The felspars are also more turbid, and in them epidote is not so prevalent. Leucoxene is rare.

12370 is a rock of the soft green type.

Minerals observed: chlorite, quartz, calcite, felspar, magnetite, apatite, epidote.

Long, thin columnar crystals of felspar, partially or wholly altered to carbonate and green chlorite, with usually a green border of chloritic scales all round the crystals, are the most prominent feature of the slide. The felspar appears to be andesine. Between these forms are clear areas of quartz with chlorite inclusions; some of the quartz appears originally interstitial, but most is doubtless secondary. There are numerous apparent intergrowths of calcite or chlorite and quartz forming a micropegmatite, and though the calcite and chlorite may be due to decomposition of felspar the structure in this case is more probably of secondary origin. On the other hand, a few small areas of micropegmatite in which the felspar is only kaolinized are regarded as original. There are a few needles of apatite, numerous grains of magnetite, and some small plates of epidote.

Though the alterations to which this specimen and 12324 have been subjected are quite different, the structure of the rocks is somewhat similar. There is even in 12370 a suggestion of ophitic structure. The rock is of doubtful origin, but is classed as originally a quartz dolerite.

12377 and 12379 are of very similar type to the preceding, but though they are undoubtedly originally the same rock their structure is more indefinite. 12377, in particular, approaches 12322 in structure, and it would seem that the difference between the two is due only to a difference in the type of alteration each has undergone.

2108 is more closely grained and has a larger amount of chloritic scales. The felspar columns are very large, and the mineral is now represented largely by calcite, chlorite, and epidote, but in places by quartz and chlorite, or quartz and calcite.

In 12378 there has been a much more complete mineral and structural alteration. There are few signs of idiomorphic felspars: the structure is distinctly granular, and the slide consists of a mixture of chlorite, calcite, quartz, epidote, and iron-ore. Yellowish epidote is particularly abundant in small platy aggregates. In part of the section the constituents are arranged parallel, as if the rock had been sheared since its decomposition. One large columnar crystal with perfect longitudinal cleavage, straight extinction, very low birefringence, and a biaxial figure has been referred to zoisite.

12310 is a dark-green carbonated chloritic rock. Under the microscope, it appears at first sight to consist of a basis of almost isotropic chlorite in which are grains and crystals of a carbonate, small plates and grains of nearly colourless epidote, and some dark-grey or brown areas with the appearance of leucoxene. Closer study, however, shows that the chloritic basis contains remains of small columnar, almost lath-shaped crystals of twinned felspar. Since there appear to be no idiomorphs of any size the whole rock seems to be composed chiefly of the laths, and the suspicion arises that it is but

a much chloritized form of the non-phenocrystal porphyrite. The grey or brown areas are resolvable under high powers into aggregates of minute brown-yellow rutile prisms and needles, so that these areas no doubt represent original ilmenite, or less probably biotite.

The structure of the rock is rather indefinite. It resembles that of the fine-grained ophitic dolerites, but also that of the non-phenocrystal porphyrites. The rock is difficult to place, but has been put provisionally amongst those of doleritic affinities.

12387 is a greyish-green rock with veinlets of quartz, with much carbonate, and with a somewhat sheared structure. The mineral constituents are chlorite, quartz, carbonate, and apparently some kaolinic material. In places forms are visible which by ordinary light resemble large decomposed zoned plagioclase crystals, but which by polarized light appear as mixtures of quartz and carbonate. Prisms and grains of brown-yellow rutile are scattered all over the slide, as also are small plates of clear quartz.

The rock shows no structure. It appears more allied to the diorites than to any other group.

12303. A weathered, dirty red and green rock of rather coarse texture. Minerals observed: epidote, chlorite, quartz, magnetite, apatite, and some rounded areas rendered rusty-red by ferric oxide.

There is a total absence of structure. The slide is a mineral mass in which the commonest mineral is a yellow and greenish-yellow epidote in plates and platy aggregates. With the latter are partially chloritized fibrous and strongly pleochroic collections of greenish hornblende forms, while in many places are patches of greenish chlorite. Quartz occurs in large clear cracked plates; there is much magnetite, and there are occasional apatite needles. In one place a turbid form resembling a columnar felspar is visible. The rock was with little doubt formerly an amphibolite.

Epidioritic Rocks.

Both 2950 and 11001 are specimens too much decomposed to call for description. They appear, however, to be composed of fibrous, sheafy, and divergent aggregates of a pale hornblende which has subsequently been partially altered to chlorite. They are both without normal igneous structure, and are, in consequence, set down as weathered epidiorites.

C. The Talc-Chlorite Rocks of more indefinite origin.

The rocks of this group are those composed largely of talc and chlorite, but of which the origin is doubtful. They vary in colour from red to dense black, but are commonly green. They are all soft.

3391. A blackish-green rock, with few recognizable minerals. Seen in section it consists of numerous fine fibres of a colourless mineral with low refractive index and high double refraction. Some radial extinction in sheaf-like aggregates is also to be observed. Grains of magnetite are frequent, as are patches of granular carbonate. Though in hand specimens the rock is serpentinous in character,

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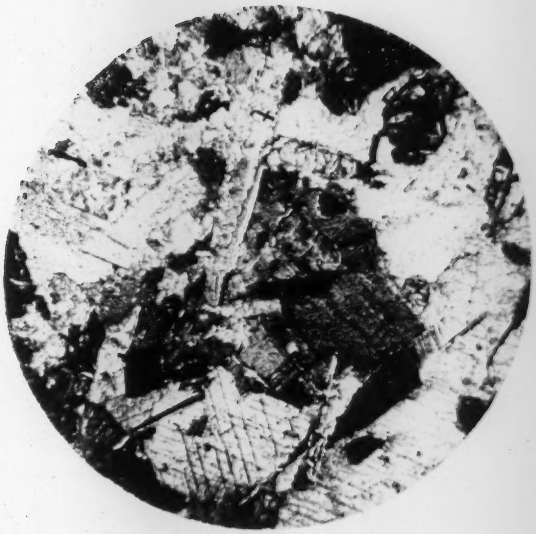


Rock-sections, Kalgoorlie.

To illustrate Mr. Farquharson's paper (see April Number, pp. 150 and 155).

in section its characters more closely agree with those of a talc-chlorite rock. An analysis made in the Survey Laboratory gave the following results :—

	Per cent.		Per cent.
$Si O_2$	47·44	*Brought forward*	91·70
$Al_2 O_3$	6·65	$Na_2 O$	·33
$Fe_2 O_3$	·76	$K_2 O$	*nil*
Fe O	6·78	$H_2 O +$	5·68
Mg O	26·68	$H_2 O -$	·78
Ca O	3·39	$C O_2$	2·06
	91·70	Total	100·55

From the relatively high percentage of alumina and ferrous oxide, it would appear that chlorite is present in fair amount. On the other hand, as potash is absent there is no sericite. The silica percentage is in the neighbourhood of that of the various epidiorites and amphibolites, and, though not much reliance can be placed on this as a criterion, it is probably that the rock has been derived from some such original.

7006 is almost identical with 3391.

12240 is grey in colour and more or less granular, and with a soapy feel. In section it is composed of a mass of minute scales and rods of a yellowish-green mineral with rather high birefringence and noticeable pleochroism, amongst which there seem to be other very minute needles of a paler colour. Idiomorphic crystals of reddish dusty carbonate are not uncommon. There are occasional fragments of quartz, and a few small pieces apparently of felspar. An analysis of the rock made in the Survey Laboratory gave the following results :—

	Per cent.		Per cent.
$Si O_2$	35·90	*Brought forward*	57·90
$H_2 O +$	4·71	Mg O	15·69
$C O_2$	9·22	Fe O	4·12
$K_2 O$	2·00	$Fe_2 O_3$	7·04
$Na_2 O$	·26	$Al_2 O_3$	13·48
Ca O	5·81	$H_2 O -$	1·84
	57·90	Total	100·07

It will be seen that the silica percentage is very low; the $C O_2$ percentage is high, and the percentage of alumina is also comparatively high. The presence of potash with a high percentage of alumina suggests the occurrence either of felspar or of sericite. The presence of the former is demonstrably present, but the identification of the latter cannot be made with accuracy. From the analysis and the optical characters, the rock would appear to be a talc-chlorite-sericite rock with carbonate crystals, and to be derived from an amphibolite or some closely related type.

12372, G.M.L. 4320 E. "Ivy"; consists of fine scales of talc, decomposed chlorite, and granular carbonate; it closely resembles 3391.

1947 (Old Thunderbolt lease, now G.M.L. 1121 E. Devon Consols Consolidated) is another dark-green chlorite rock, which consists of lenticular areas of talc and carbonate streaked out in parallel

directions, and surrounded by almost isotropic green chlorite. Crystals of carbonate are also visible, and there are occasional small plates of quartz. Brown-yellow rutile is rather common in grains and prisms.

12315 (shaft about 80 ft. S.E. of S. corner of G.M.L. 4161 E.) is a reddish rock with small plates of quartz, areas of greenish chlorite, many small brilliantly polarizing flakes that have been referred to talc, and numerous brown-red dusty aggregates and crystals. As the latter show in places distinct rhombic forms, they are, in all probability, forms of ferriferous carbonate that have been oxidized. Veinlets of quartz penetrate the rock.

12366 (dump 11 ch. N.N.W. of N. corner G.M.L. 4337 E.) is a soft greyish-green rock with a reddish tinge. There are again ferriferous carbonate crystals, and remains of small twinned, columnar, or lath-shaped crystals of felspar. The rock is of doubtful origin. It may be either a chloritized or somewhat carbonated form of the keratophyre, or it may be of amphibolite origin.

11083, "Tabby Cat" (Gibson), is a talc-chlorite rock with crystals of a carbonate. There are pleochroic halos round brown and black crystals of ilmenite in chlorite.

D. Rocks of Doubtful Origin.

1. *The Fuchsite Rocks.*

These specimens are more or less identical in appearance with those already described by the writer from other localities,[1] with the exception of 12317, which is a pale-green quartz rock with green micaceous scales in strings on the surface; they are all heavily carbonated, partly siliceous, with white quartz, and to a greater or less extent pyritic. The fuchsite occurs in films and scaly aggregates all over the rocks. Most noteworthy, however, as tending to throw some light on the mode of origin of the rocks, is the occurrence in 10439 of a development of tourmaline needles, associated with a fresh felspar and large idiomorphic crystals of a carbonate. The nature of the felspar has not been definitely established, but from measurements already made it appears to be albite. The significance of the occurrence of tourmaline has already been pointed out. The origin of the chromium oxide that has given rise to the fuchsite is still, however, to be accounted for. Attempts have already been made to explain its origin in definite terms, but one great difficulty has been that for various reasons no field evidence of its occurrence of any service can be obtained. The same difficulty has been met with in the area under consideration. The specimens were obtained from dumps of shafts to which access is no longer possible. The chromium must, however, be regarded either as original in the rock or as introduced by circulating lateral or ascending solutions to which the carbonates, the silica, and indirectly the tourmaline are due.

[1] Bulletin No. 43, G.S.W.A.: Observations on some Rocks from Ingliston, Extended Mine, Meekatharra. Also Bull. No. 47, G.S.W.A., Petrological Notes, p. 92.

It is known that the water of hot springs does contain not only CO_2 in solution but also small amounts of Cr_2O_3. Traces of chromium are contained, for instance, in the deposits of hot springs at Carlsbad.[1] On the other hand, there are in these fuchsite rocks small grains of a black or brown colour, often surrounded by the micaceous mineral, which may be chromite or picotite. At present, however, no definite views as to its origin can be put forward. It must be noted that in the cases previously described no tourmaline has been identified in association with these rocks, so that its development may be subsequent to the formation of the carbonate.

10439. A green and white, partly siliceous, carbonate rock with tourmaline, pyrite, and felspar.

The characters presented by the rock are essentially the same as those of similar rocks already described. Briefly, the section consists of a granular mass of carbonate, quartz, sericite, and fuchsite, and brown and black grains surrounded by green mica. There are small aggregates of rutile needles, some in the carbonates. Apparently a marginal peculiarity is a mixture of quartz, fairly fresh felspar, and numerous long prisms of a tourmaline with dichroism from almost colourless to brownish-green. In places the mineral is found to be apparently enclosed both in the carbonate crystals and in the felspar. (Plate VII, Fig. 4.)

11028. A dark greyish-green rock with strings of pyrites, veinlets of a whitish carbonate, and with a rather faint green tinge. In section, besides the ordinary granular mixture, there are fragmentary plates of a partially granulitized clear felspar that appears to be albite. It is in places more or less sericitized.

12257 is similar to 11028, but more heavily carbonated, and shows several veinlets of quartz with some cryptocrystalline areas of very low birefringence.

In 12256, which is a light-grey carbonate rock with greenish spots, there are much granular carbonate, small plates of quartz, and long columnar striated felspars that have been partially replaced by sericite and carbonate. There are also laths of altered felspar and a large number of opaque, squarish, and rounded granules that appear whitish or yellowish by reflected light. It was impossible to identify the felspar, but the appearance of the rock is such as to suggest the possibility of its having been the keratophyre. The small green spots in the hand-specimen are very difficult to pick up owing to their small size and the presence of sericite. It seems unlikely, however, that they are inclusions.

12317. Appears in section to be made up of quartz plates of various size rendered dusty by minute fibres of sericite and small bluish-green patches presumably of fuchsite.

2. *Rocks possibly of Plutonic Origin.*

11096. M.C. A weathered grey-green rock with numerous grains of pyrites and occasional long thin columnar and pale greenish felspars visible.

[1] Beck, *The Nature of Ore-deposits*, vol. ii, p. 426.

Minerals observed: quartz, felspar, pyrite, magnetite, granular calcite, chlorite, a micaceous mineral (muscovite).

There are long broad columnar crystals of a felspar showing either only Carlsbad twinning or none at all; other crystals, tabular as well as columnar, show broad albite lamellation and symmetrical extinction angles as high as 14°, 15°. The former are doubtless orthoclase, the latter andesine or a basic oligoclase. Quartz is abundant in a few plates that are almost idiomorphic, but mostly in shapeless areas. Intergrowths of felspar and quartz are very frequent, and of large extent, the felspar being either micacized or kaolinized. In some places tabular felspars appear like islands in a sea of clear quartz; in others the felspar of an intergrowth is optically continuous with a tabular crystal. Instances are to be seen where felspar crystals have been broken across, and in these the cracks have all become filled with clear quartz.

Granular patches of calcite and magnetite and also of chlorite, with crystal outlines, may represent an original ferro-magnesian. Flakes of a colourless micaceous mineral occur sporadically and have been referred to muscovite. Pyrites is common in the rock in grains of various size. There is no distinct porphyritic structure.

The rock is difficult to name; it resembles some hornblende granites and quartz diorites, but, though no ground mass is noticeable, it more closely approaches in character a granite porphyry. The great amount of clear quartz and the infilling of cracks in the felspars by this mineral suggests a partial metasomatic replacement of some of the felspar by quartz.

2918 is a grey rock with dark-grey spots in a lighter rock mass, and with veins of pyrites. In section are visible large shapeless plates of clear quartz, some leucoxene areas, and much granular pyrites in a granular mass of carbonate, quartz, muscovite, and sericite. There are remains of platy felspars now sericitized, and occasionally what appear to have been intergrowths of quartz and felspar, the latter sericitized.

No noticeable rock structure now remains, so that it is impossible to come to any conclusion as to the nature of the original rock.

5. Conclusions.

Briefly, the main points which emerge from a consideration of the area dealt with in this paper are these. The earliest rocks and those that form the greater portion of the area are greenstones which comprise masses of doleritic or gabbroid type, others of amphibolite without doubt derived by extreme dynamic metamorphic action from the former, and talc-chlorite rocks which probably represent the extreme phase of chemical and dynamic alteration both of the dolerite and of the amphibolite. The movements which contributed to the production of the hornblende of the amphibolite from the augite of the dolerites or gabbros not only produced a shearing in the rocks themselves, but developed actual fissures in the rock masses, a main series at right angles to the direction of stress and no doubt a minor at right angles to the latter. Moreover, along several lines the shearing and crushing stresses were probably greater than along

others, with the result that distinct lines of weakness were produced in the rocks.

At a later date, along these lines of weakness and doubtless along various fissures in the mass, there were intrusions of a highly acid dyke-rock rich in soda and with frequent hornblende phenocrysts—the albite—porphyrite or keratophyre. That this is decidedly later in origin than the greenstones is proved by its occurrence in tongues in them, and by the frequent examples in one locality of included chloritic xenoliths.

Accompanying the acid intrusions were boric vapours which not only caused the production of tourmaline both in the keratophyre and in the quartz leaders, but which, in association with other gases, without doubt exerted a pneumatolytic action on the surrounding rocks. Harker[1] has briefly described the main views now held as to this type of alteration. According to him, with the completion of crystallization in a rock magma the combined water and other volatile substances must be disengaged. The bulk of these are collected in druses and geodes or occupy fissures in the now solid rock body. Such cavities and fissures may be sufficient to permit of a general circulation through the rock mass. As cooling proceeds, however, some of the compounds crystallized at higher temperatures cease to be stable in the presence of the concentrated gaseous residuum and are decomposed with the production of new minerals. The volatile substances may or may not enter into the composition of these new minerals, but in general they do so at a greater extent at this stage than during the magmatic crystallization.

The pneumatolytic agents themselves are merely the final residuum of an igneous rock magma, and the processes are conducted at temperatures more or less elevated, though progressively declining. It is probable, therefore, that the tourmaline of the keratophyre has been produced during the later stage of the consolidation of the magma and possibly by action of the boric vapours on some of the felspar.

Further, in the lode formations kaolin and sericite are particularly abundant, and, as Flett has pointed out, this kaolinization and sericitization may be attributed in great part to pneumatolytic action. Moreover, the action of the vapours was doubtless also exerted on the surrounding greenstones, causing a propylitization which has given rise to some at least of the soft greenish chloritic rocks.

When the high acidity of the dyke is taken into consideration, and also the fact that frequent cases occur of the quartz leaders enclosing tourmaline needles, most of the leaders and of the auriferous quartz of the lodes may be regarded as genetically connected with the dyke, as being the later more acid or wholly acid phase in which the rarer mineralizers—in this case boric vapours—were particularly abundant. It is probable also that auriferous veins will be found not only at the junction of the dyke with the greenstones, but in some cases for some distance into the greenstones themselves.

[1] Harker, *Natural History of Igneous Rocks.*

III.—An Inquiry into the Origin of "*Batrachioides* the Antiquor" of the Lockport Dolomite of New York.[1]

By E. M. Kindle.

(PLATES VIII AND IX.)

THE physical history of sedimentary rocks is written in characters which sometimes baffle the skill of geologists to interpret. This may be because geologists are prone to devote too little time to the study of rocks in the making, and too much to the finished products of sedimentation. It is well to remember that the most unpromising pool or bit of lake shore may hold the key to the most perplexing of these hieroglyphics.

A brief review of the history of the various attempts to explain certain curious impressions found on the Niagara dolomites of Western New York will illustrate the need of closer observation and study of some of the phenomena of our ponds and lakes resulting from the interaction of wind and water.

The highest beds of the Lockport Dolomite which are exposed in the Niagara Falls region have been cut through by the Erie Canal near Pendleton, N.Y. The rock here is a thin-bedded, black or steel-grey dolomite with numerous thin films of black shale separating successive laminæ in some of the beds. Some of these beds show gently concave plates of limestone which have the surface completely covered by shallow contiguous pits (Pl. VIII, Fig. 1). These curious impressions are usually about 1 inch in width and have a depth of from $\frac{1}{4}$ to $\frac{1}{2}$ in. They are remarkably uniform in character, as shown in the Figure. Well-developed ripple-marks with an amplitude of $1\frac{1}{2}$ inches appear on the surface of closely associated beds.[2]

Professor James Hall,[3] who appears to have been the first to observe these impressions, ascribed them to the action of inorganic agencies akin to those which produce concretionary structures.

In 1850 Professor Benjamin Silliman brought these curious structures to the notice of the American Association for the Advancement of Science[4] and attributed their origin to the agency of great numbers of gregarious fishes. He stated that excavations of similar character and appearance are now made by tadpoles in shallow pools. The eminent naturalist Alexander Agassiz[5] was inclined, however, to doubt the ability of tadpoles to produce the regular shallow pits on mud which Silliman and Hitchcock ascribed to them. A few years later Professor Edward Hitchcock referred to the Lockport Limestone impressions in connexion with the discussion of very similar markings on the Triassic sandstones at South Hadley, Massachusetts. Professor Hitchcock's remarks bearing upon the kinship in origin of tadpole nests and the impressions on the Lockport Limestone are as follows: "I had been led to doubt the tadpole origin of the South Hadley and New York specimens, by the fact that in many cases the cavities were arranged in lines, and sometimes too it was clear that

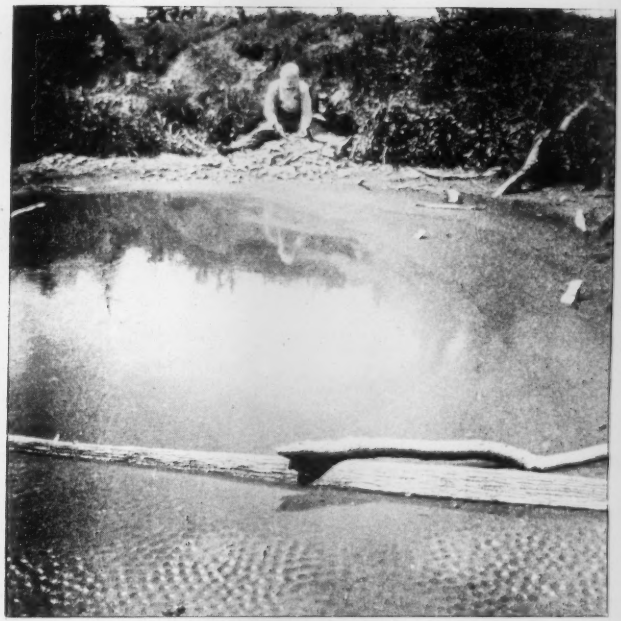
[1] Published with the permission of the Director of the Geological Survey of Canada.

[2] Folio U.S. Geol. Surv. No. 150, pl. xxv.

[3] Geol. New York, 1843, pt. iv, pp. 92–3, fig. 29.

[4] Proc. Amer. Assoc. Adv. Sci., vol. iv, pp. 10–12, 1850.

[5] Ibid., p. 12.



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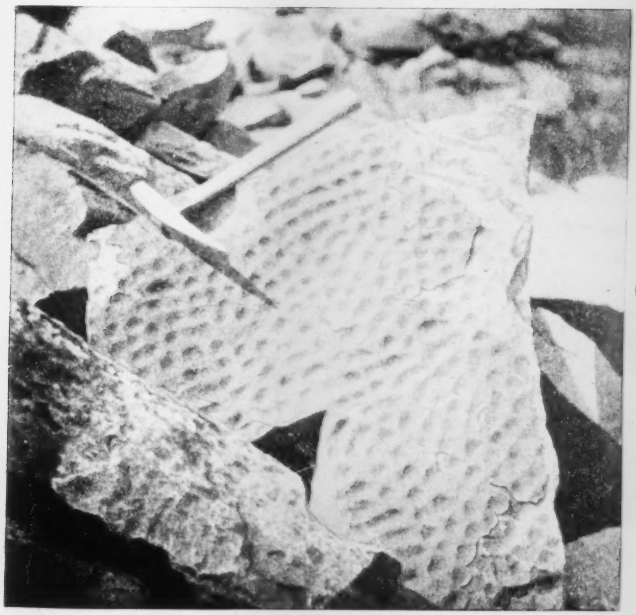


1

Photographs of (1) *Batrachioides antiquor* and (2) 'Tadpole nests'.

they occupied ripple marks. But I found the same thing at Tadpole City. Deep as the hole is, and slight as could be any aqueous current there, I found that ripple marks, of about the same width and depth as those on the rocks, had been formed over a part of the bottom, and of course the tadpoles chose the furrows rather than the ridges for making their holes. Another circumstance showed how their holes came to be arranged in lines more or less, even where there were no ripple marks. As the water became shallow, I found that the tadpoles would collect in great numbers just along the surface of the water, at its edge, and there of course would the work of excavation be most thorough. But as the water was constantly sinking, successive rows would thus be produced. In fact, until the rains destroyed this city, I could not see but that all the phenomena on the rocks were reproduced. And I know that these cavities were formed by tadpoles, because I saw the animals at work in making them. And had the spot been so situated that a gentle influx of water as by a tide, or a freshet, should bring in mud to fill the cavities before they were erased by the rains, they might have been preserved indefinitely; and perchance sometime be converted to rock, such as the South Hadley shale, or the Niagara sandstone." [1]

Professor Hitchcock evidently considered the 'Niagara Sandstone' (Lockport Dolomite) impressions to have originated in a manner analogous to those of the Connecticut Sandstone which he named *Batrachoides nidificans*.[1] He suggested tentatively that these impressions represented 'mud nests' of Silurian batrachians and proposed the name *Batrachoides* the *antiquor* in the following passage: "And what is still more important, the facts would prove the same thing in respect to a period so early as the time of the Niagara Group of New York, which belongs to the lower part of the Upper Silurian; an epoch far earlier than any other in which traces of batrachians have been discovered. Therefore I have called the New York impressions *Batrachoides* the *antiquor*."

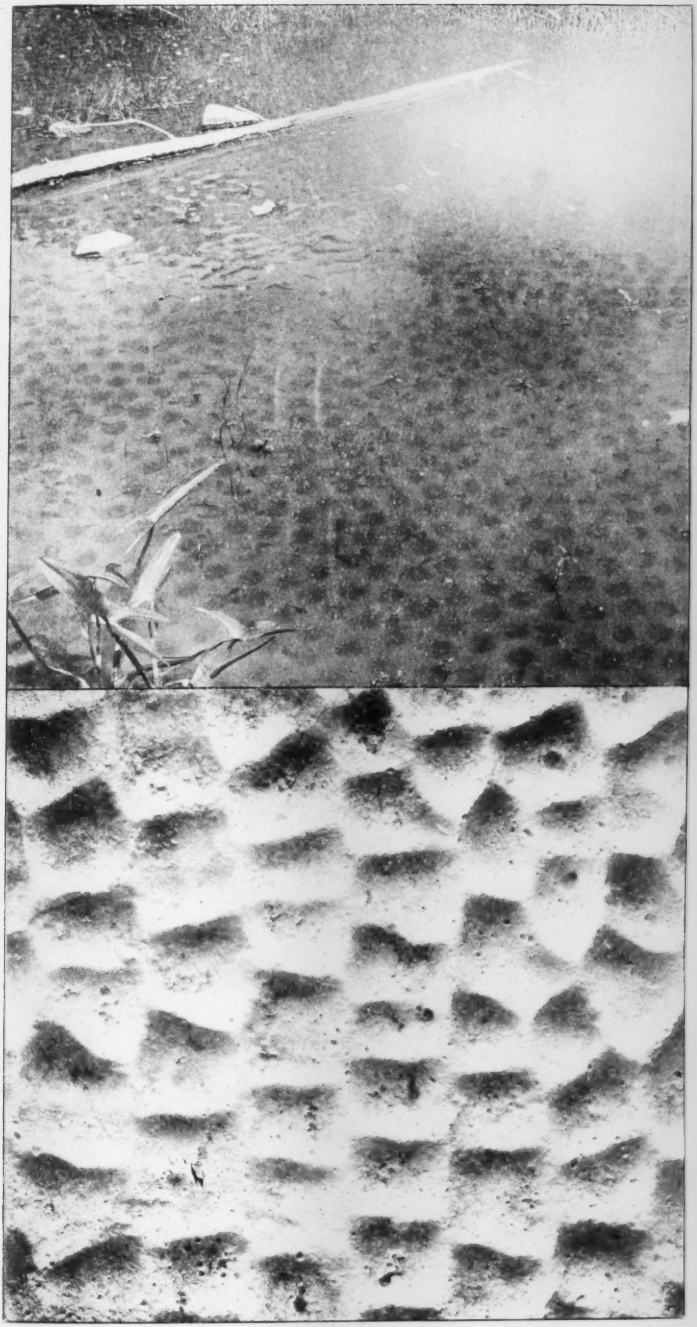
The writer recently published [2] a photograph of a specimen of Hitchcock's *B. antiquor*, but postponed any discussion of the nature of the impressions till the present occasion.

Regarding Professor Silliman's suggestion that the impressions represent the work of small fishes, it may be observed that very few fishes are known in the Silurian anywhere, and that the only fish-remains which have been discovered in the Silurian formations of this region were obtained from beds 100 feet or more below the beds under discussion. With respect to the batrachian origin of the impressions, it may be noticed that thus far no direct evidence has appeared that any representatives of the Amphibia were in existence as early as Silurian time. Comparison of the accompanying photograph of the Lockport impressions, with Hitchcock's figure of the Connecticut sandstone impressions called *B. nidificans*, strongly suggests that the two have had a similar origin. There is no doubt either in the mind of the writer that the dimpled surfaces on the Lockport Beds are the product of the same agencies which now produce 'tadpole nests'.

[1] *Ichnology of New England*, 1858, pp. 121-2.
[2] Folio U.S. Geol. Surv. No. 150, pl. xxv.

In accepting the conclusion of Hitchcock, that the Lockport and Connecticut sandstone impressions originated in a manner analogous to 'tadpole nests', it will be necessary to reconsider the question of origin of the 'nests'. As already noted, so eminent a naturalist as Alexander Agassiz doubted the ability of tadpoles to produce the impressions ascribed to them. There can, however, be no doubt that tadpoles are sometimes found associated in shallow water with the 'nests' which have been attributed to them, but the association of the two will not, taken alone, establish a causal relationship between them. The two photographs (Pl. VIII, Fig. 2, and Pl. IX, Fig. 3[1]) show the appearance of the structures called 'tadpole nests' by Hitchcock and others. The photograph (Fig. 2) shows a shallow pool which occupied the bottom of a small abandoned quarry. The writer spent several hours about the sides of this pool collecting fossils. It thus happened that abundant opportunity was afforded while cracking open blocks of the adjacent limestone to observe closely the behaviour of the tadpoles associated with these pits. When these observations were made the size of the pond had been reduced by evaporation till it was generally less than 1 foot in depth, and the hundreds of tadpoles in the water were evidently suffering from over-population and reduced food supply. A number of the tadpoles which had died, presumably as a result of this condition, were furnishing food to the survivors. In feeding upon their deceased associates, five or six tadpoles usually attached their mouths to the body of the dead batrachian, and in this way a ring of half a dozen vibrating tails almost constantly surrounded the bodies of each of the victims. During the feeding the movements of the concentrically disposed tadpoles tended to disturb the sediment immediately below. At the time the observations were made the writer believed that the shallow pits had been produced entirely by these activities of the tadpoles. But more recent studies of interference ripples has led him to conclude that the 'nests' are interference ripple-marks slightly modified by the tadpoles. The point may be raised that the photograph of interference ripples here reproduced (Pl. IX, Fig. 4) shows the pits separated by sharp angular ridges, whereas the 'nests' have comparatively flat or gently rounded partitions. The writer has found that different examples of interference ripples show a rather wide range of characteristics with respect to this feature. Just as ordinary ripple-marks show crests, which in examples produced under different conditions range from sharply angular to nearly flat or rounded, so interference ripples exhibit corresponding variations of type. Successive observations of one set of interference ripples continued for three days by the writer have also shown that ageing of the impressions under the influence of a shifting direction of the wind tends to alter angular partitions to rounded ones. The comparative rarity of the so-called 'tadpole nests' affords strong evidence that they are the product of the wind rather than of tadpoles. The writer has observed many scores of ponds with tadpoles,

[1] The writer is able to publish this photograph through the courtesy of Mr. G. K. Gilbert.



3

4

Photographs of (3) 'Tadpole nests' and (4) interference ripple-marks.

but has only once seen the dimpled surface called 'tadpole nests' by Hitchcock associated with them. Inquiries have been made of a number of zoologists for information concerning the alleged tadpole habit of making nests, but the writer has been able to find no zoologist who was aware that tadpoles ever indulged in such a habit. If such structures were ever produced by tadpoles one might reasonably expect to find them generally associated with these creatures. These considerations, together with the fact that the oscillation of the water under certain conditions of wind action produces structures similar to the so called 'tadpole nests', lead to the conclusion that those observed by Hitchcock and others are interference ripple-marks, perhaps slightly modified in outline by tadpoles.

Comparison of the photograph of the impressions on the Niagara Dolomite with the photograph of interference ripples which was made from moulds of interference ripples taken under water at Britannia beach, Ottawa, indicates clearly a similar origin for both. The strong resemblance of the two photographs is such that one can scarcely doubt that they have had an analogous origin. Interference ripples are much less common than the wave-like type of ripple so frequently seen in shallow waters. They are developed under shallow water[1] in which the ordinary wave generated by the action of the wind on the surface is split up into two or more sets of oscillations moving in different directions. The gradual movement of fine sediments by such conflicting currents, which may proceed so slowly as to be nearly imperceptible to the casual observer, results in the coarse cell-like structure shown in Pl. IX, Fig. 4. The small eddies and cross currents which originate about the ends of bars, piers, or stranded logs are favourable localities for the development of interference ripples. The cast of the interference ripples shown in Fig. 4 was made in water about 6 inches deep, which was protected from any but the lightest wave action by stranded logs on all sides. If the writer's interpretation of the Lockport lime-stone impressions is correct, they too were formed in shallow waters in which bars probably furnished the special conditions required for the development of interference ripples.

EXPLANATION OF PLATES VIII AND IX.

PLATE VIII.

FIG. 1. Dimpled surface on upper beds of Lockport dolomite at Pendleton, N.Y., "*Batrachioides* the *Antiquor*" of Hitchcock.

,, 2. 'Tadpole nests' on bottom of shallow pond, Hamilton County, Ind.

PLATE IX.

,, 3. Photograph of 'tadpole nests' in small pond. By W. W. Gilbert.

,, 4. Interference ripple-marks. Photograph from mould of cast taken under water at L. Deschenes.

[1] The writer's observations have been limited to shallow water, but it is probable that interference ripple-marks would be produced in water of considerable depth where a rocky ledge or other obstruction to normal oscillation of the water generated by wave action extended into a sandy bottom.

IV.—Studies in Edrioasteroidea. IV. The Edrioasters of the Trenton Limestone.

By F. A. Bather, M.A., D.Sc., F.R.S.

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(PLATES XIII–XIV.)[1]

(*Concluded from p. 125.*)

THE Cover-plates of the radial grooves are preserved here and there in specimen A, notably over the oral centre (Pl. X, Figs. 1, 2, 5, 7, 8), but in B they are preserved over the whole of the grooves and the mouth, though pressed down on to the floor of the grooves and into the peristome (Pl. XI, Fig. 1). Cover-plates are also present in the British Museum specimens, and are almost complete in E 16054.

Each cover-plate corresponds in position with a floor-plate; so that, like the floor-plates, the cover-plates form a double series of alternating plates meeting in a zigzag median suture. The almost straight or slightly rounded outer margin of each cover-plate fits into a bevelled facet just within the rounded edge of the radial groove where the floor-plate begins its downward slope (Pl. X, Figs. 5, 7). This feature is well shown in specimen B, and there the floor-plate also shows, on each side of the facet, and distinct from the peripodium, a slight depression, possibly for the insertion of a muscle or ligament, or possibly for the reception of the accessory cover-plate shortly to be described.

From their facets the cover-plates stretch across the radial groove, either in a straight line (Pl. X, Fig. 5) or slightly arched upwards. Often, however, as in B, they have been pressed down into the groove, whether by contraction of tissues after death, or, as is more probable, by the pressure of the superincumbent rock.

The cover-plates abut closely, in tessellate fashion, when closed in the normal position over the radial groove. When pressed inwards, however, as in B, they have sometimes been made to imbricate with adoral overlap. This suggests a possibility of the converse action, namely, that in life they may have assumed a similar imbricate arrangement when they opened outwards, thus forming a slight gap between adjacent plates.

A gap may also have been produced by the opening of the accessory cover-plates. These are minute triangular plates frequently to be observed, one at the outer end of each suture between adjacent cover-plates, and therefore lying just over the pore (Pl. X, Fig. 8). Minute depressions in the floor-plates have already been mentioned as possibly the facets for their reception. These accessory plates are not always to be distinguished, but this may in some cases be due to the state of preservation, and the difficulty of detecting the sutures bounding such minute structures. When clearly seen, it is obvious that they were definite elements demanding explanation, and not caused by accidental cracks.

On the other hand, there is in E 16054 an occasional appearance of separate small plates along the median suture. In this case the appearance is probably due to fracture. The specimen has been

[1] Plates X–XII appeared in the March Number, pp. 115–25.

crushed, but the arched cover-plates, instead of being pushed into the groove, have resisted the pressure and given way at the summit of the arch.

Here we may turn to the differences presented by the subvective skeleton of *E. levis*. The floor-plates are not separated from the interradial plates by a continuous line of curved sutures, but join them by irregular angular sutures, varying in accordance with the outline of the plates against which they abut. And, just as they merge in this way into the interradials, so are they not distinguished from them by so sudden a rise above the general level as is the case in *E. bigsbyi*. Thus the rays of *E. levis* are less conspicuous, and, by reason of this as well as of their more regular curvature, have not that curious appearance of independent life.

The relations of the floor-plates to the cover-plates are also slightly different. A single cover-plate, instead of abutting on a single floor-plate, abuts as a rule on two. Consequently each floor-plate, instead of a single curved facet for its cover-plate (with a possible minute facet at each side thereof for an accessory plate), has one long curved facet for the cover-plate hinged to it, and a very short straight facet where the adjacent cover-plate plays against it. The longer curved facet, where distinctly observed, is on the distal side of the floor-plate. There are no accessory plates.

On the floor of the groove, the perradial zigzag channel is less marked, and the side-branches from it less pronounced. The surface of the plates between these branches is gently rounded, almost flat, and not ridged. The outer pore-depression and the inner, more adradial, depression are well marked, but not very distinct from one another. The specimens do not yield convincing evidence for or against the passage of pores to the interior.

The appearance of additional cover-plates along the median line is very strongly marked in certain regions of E 15900 (Text-fig. 2). These regions are just where the ray curves more sharply and passes along the periphery, and is therefore most subjected to both natural torsion of the cover-plates and post-mortem pressure. The former force seems to have induced an adcentral bending of the cover-plates as they approach the median line, and this is best seen towards the proximal end of the disturbed region (Fig. 2, II). Nearer the periphery the latter force has compressed the grooves so that the cover-plates have been raised, as in E 16054, and pushed together. Consequently their adcentrally directed ends have been broken across, and in some places seem to form a double row of small plates, alternating with each other and with the main cover-plates from which they are derived (distal end of Fig. 2, II). Occasionally each of these small plates is again divided by an apparent suture transverse to the median line of the groove, so that two small plates go to each main cover-plate (Fig. 2, III). The regularity of these appearances is diminished in proportion as the specimen is cleaned and carefully examined. None the less, the divisions between the plates look like true sutures, and they may represent a structure that arose naturally during life rather than the consequence of some accident or of post-mortem pressure.

Tegminals.—In both species, where the grooves meet at the peristome the cover-plates continue round them, and so form a roof over the actinal centre. No special plates are developed here, but all are serially homologous with the other cover-plates and have, in *E. bigsbyi*, the same accessory plates. There are, however, two differences: (1) in order to cover the space, these plates are rather larger and less regular in shape than normal cover-plates; (2) they appear suturally united to form a solid tegmen, and in consequence are rarely pressed into the mouth-cavity as in B, but are frequently preserved in place even when the other cover-plates have disappeared (Pl. X, Fig. 1).

The Peristome, which lies beneath this tegmen, consists of a roughly circular opening, surrounded by a frame. Owing to the persistence of the tegminal plates, the peristomial structures are rarely well shown, but it has proved possible to develop them on the right side of specimen A (Text-fig. 3). Here the floor-plates of one side of the right posterior ray curve round the right posterior interradius and meet those of the adjacent side of the right anterior

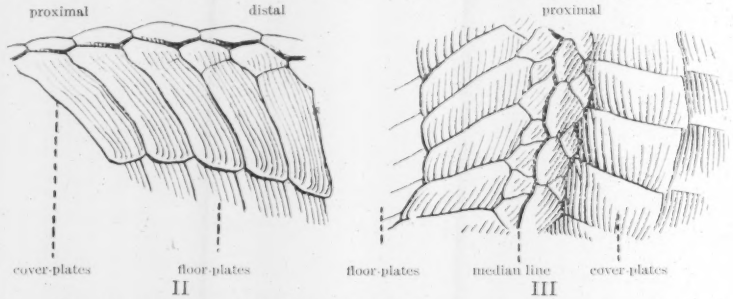


FIG. 2. Cover-plates of *Edrioaster levis*, from the adoral face near the periphery of the holotype. × 6 diam.

II. From the left anterior ray, showing the curvature of the admedian tract and its gradual change into a distinct plate.

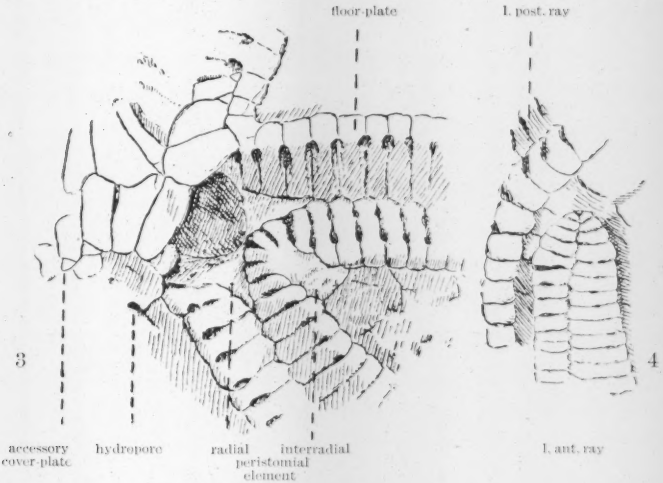
III. From the anterior ray, showing small plates similar to those in II, but with yet smaller plates between them.

ray, so that there is a fan-like arrangement of the pore-bearing sutures about the interradius. Four of these plates, two from each ray, appear to be fused at their marginal ends; and the solid plate thus formed stretches centrifugally along the interradius, serving as a fixed abutment for the adjoining floor-plates to the number of $2\frac{1}{2}$ on each side. In other specimens five floor-plates may compose this interradial plate. Rarely, as in E 16172, there are two such compound plates formed in an interradius. These plates were noticed by E. Billings (1854, p. 273), who doubted whether their pores penetrated to the interior, but observed and figured a pore in the posterior angle as larger than the others.

As the floor-plates curve round to meet those of the next radius, they become separated from the corresponding floor-plates on the opposite side of their own radius. Between the two rows on the floor of the groove, there seems to be intercalated another skeletal

element, over which the groove itself passes centripetally down into the thecal cavity. As seen from above each of these radial flooring elements has a roughly triangular outline, and meets its fellows to left and right by its basal angles, thus forming a continuous ring round the central space. In 1854 (p. 271) E. Billings figured these plates as seen from the interior (fig. 11) and in section (fig. 12). He described them as triangular, and partly covered by the plates at the interradial angles, and as having "an elevated border on the side next the mouth, below, caused by the bending down of the plate."

To obtain a clearer idea of the relations of these apparent radial mouth-plates, I have removed the adapical structures and the matrix from the under side of rays III and IV in the peristomial region of E 16172. After three months of this labour it has been possible to produce Fig. 2 of Plate XIV, but the structures are still rather



EDRIOASTER BIGSBYI. Specimen A.

FIG. 3. Portion of the peristomial region more developed by preparation than in Plate X, fig. 1. × 4 diam.

,, 4. The distal end of the left anterior ray, showing floor-plates only. × 4 diam.

difficult of interpretation. The peristome, as viewed from the inside of the test, is surrounded by a stout frame forming an elevated border. This border is flattened rather curiously, and is widest on the perradii, so that while its inner or adcentral margin is approximately circular, its outer or adperipheral margin approaches a pentagon with radial angles. The interradial tracts of this mouth-frame are, it is clear, composed of those floor-plates which, as already described, are fused to form the adoral or proximal interradial plates. The pores between these plates penetrate to the interior all the way round, though they decrease in size as they near the interradius. The radial tracts of the frame likewise seem to be composed of the floor-plates, which are here enlarged at their perradiad ends. There do not seem to be any

distinct interradial elements, but the appearance of such in external view, as described above, is almost certainly due to the overlapping of the perradiad ends of the proximal floor-plates. The difficulties of interpretation are due to the very close union of the plates to form a rigid mouth-frame, and to the cracks that develop during the process of preparation.

There appears to be in each ray some slight projection of the interporal region of a pair of floor-plates, each forming a process directed away from the perradius, and placed at the spring of the elevated border. These are not so regular that one can infer their normal and constant presence in every ray of all individuals, but they may well have some significance as processes for the attachment of muscles or other internal organs.

There are no traces of any other hard mouth-parts or of any skeletal connexion between the mouth-frame and the lobes of the adapical integument.

These peristomial structures are the stereom counterpart of the various channels and cavities observed in the internal cast of *Edrioaster buchianus*, and confirm the interpretation of those cavities offered in Study II, pp. 197, 198. Their relations to the soft parts will be discussed later.

The Interradial Areas are irregular in shape according to the varying curves of the radial grooves. In A, the posterior area, from the concavity of the left posterior ray to that of the right posterior, is 19·5 mm. across; but a part of this is occupied by the recurved end of the right posterior groove. Of the other areas, the widest is the left anterior, which measures 13 mm. at its widest part; and the narrowest is the right posterior, which measures about 7·5 mm. near the periphery (Pl. X, Fig. 1). In B the same general relations obtain (Pl. XI, Fig 1). In E 15930 the chief difference seems to be that the left anterior area is relatively wider. In *E. levis*, on the other hand, the relations, owing to the solar curvature of all the rays, are quite different; thus, in E 15900 the measurements are: posterior, *circa* 24 mm.; left and right anterior, both 12 mm.; right posterior, *circa* 16 mm. (Plate XII).

The Interradial plates are irregular polygons, apparently with no definite arrangement. A single plate of moderate size abuts on the compound interradial element of the peristomial frame and is usually bordered by about four floor-plates on each side. This is followed by a number of plates different in each interradius. Thus in A the numbers are: l. post., 2; l. ant., 3; r. ant., 4 or 5?; r. post., 4. In B these plates almost agree in numbers and arrangement with those of A. In these two individuals the curvature of the rays is almost exactly the same, and there is also a remarkable general similarity in the number, shapes, and arrangement of the interradial plates. This similarity may imply either that the plates are heritable morphological elements, or that similar mechanical causes acting upon an indifferent plate-forming tissue have produced a similar breaking-up of the stereom. That the latter is the true interpretation seems to be proved by the other specimens, for in them the same plates cannot be identified.

The interradial plates are stout, those not far from the periphery in E 15930 having a thickness of 1 mm. and over. They are tessellate, with vertical sutures, but, as already described, dipping with oblique sutures under the radial floor-plates. There are no pores through or between the plates. The surface in well-preserved tracts is coarsely pustulate (Pl. XI, Fig. 1). The pustules are distinct, and spring from an irregularly reticular surface. E 16054, being a small and presumably a young individual, shows the pustules rather faintly and of smaller size than in the other specimens; a large proximal plate in the left anterior interradius has the pustules distributed about 9 to 1·5 sq. mm. In E 15930, an individual of more than twice the diameter, the pustules on a similarly placed plate run about 9 to 3 sq. mm.

These pustules are not due to the breaking up of growth-lines by radial stresses, but they may very well have been tubercles bearing minute spines. Such spines, being very loosely attached, would readily fall off after death, and would in any case escape observation owing to their minute size. I have searched for them in the very small amount of available material, but in vain, unless a tiny rod (·8 mm. × ·25 mm.) in the left anterior interradius of E 15930 may possibly be one.

The specimens of *E. levis* differ in having no distinguishable pustules, a feature to which my attention was first directed by Mr. Walter Billings. The exposed surface of these two specimens has been somewhat worn (one had apparently been trodden on), and this has exaggerated the smoothness. When other parts were freed from their protecting matrix they presented a surface that might be described as slightly vermiculate, or perhaps more accurately as 'scrobiculate'.

The Anus is well shown in specimen A (Pl. X, Fig. 1). It lies between the distal end of the right posterior groove and the bend in the left posterior groove, and is surrounded by a number of small plates, which must have lent greater flexibility to the test in this region. Twelve of these plates meet round the actual opening, from which the sutures between them radiate (Pl. X, Fig. 9). They are not of equal length or width, and meet the smaller surrounding plates quite irregularly. There is no imbrication. The area covered by small plates rises up in a slight dome above the general level of the interradius, but at its summit is again pushed in just round the anal opening, possibly in consequence of post-mortem contraction. The anal dome is not sharply defined on its right side, but seems continuous with a general swelling of the thecal surface in that direction. The rectum may have lain under here, and this, if so, would indicate that the gut had a dextral coil. The similar appearances in *E. buchianus* have received a similar interpretation from Professor Jaekel and myself (cf. Study II, p. 199).

In specimen B (Pl. XI, Fig. 1) the periproctal plates are disturbed, but the dome is discernible, as also the swelling on its right. In the two specimens of *E. levis* the periproctals are numerous and small, but do not appear to be elongate to any considerable extent.

The Hydropore, or at least the thecal opening which I thus identify,

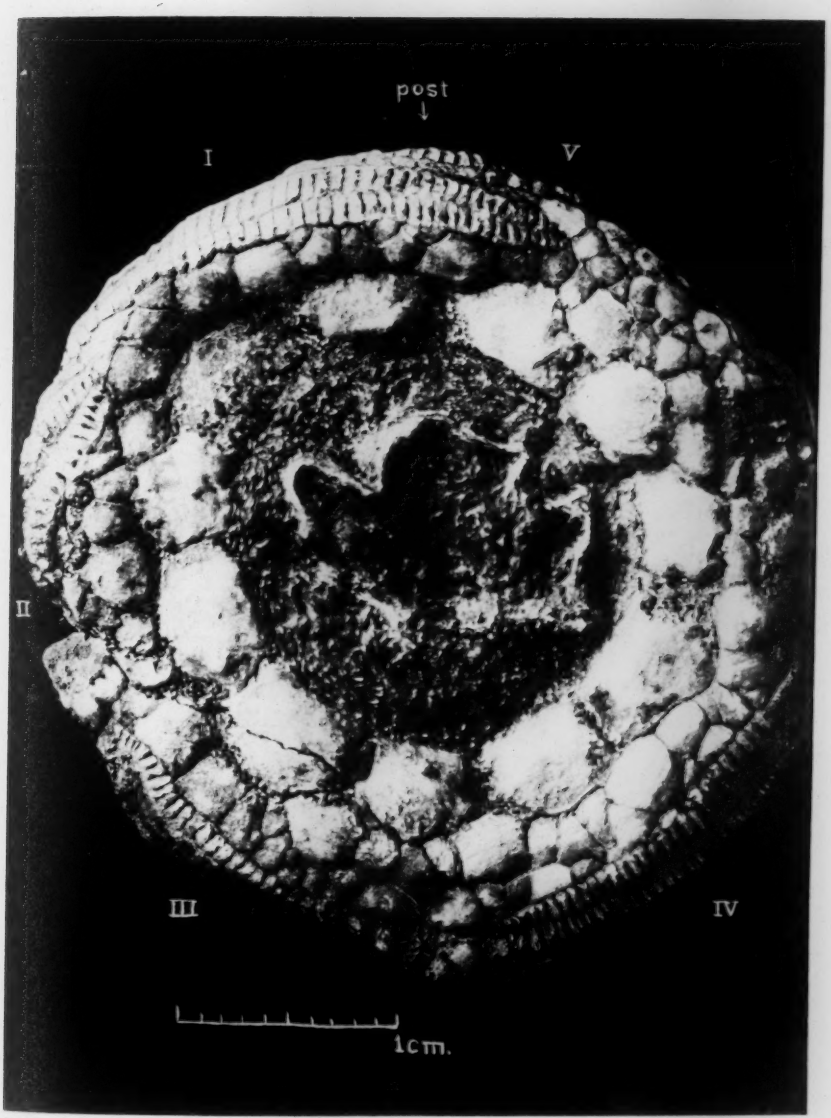
lies at the adoral end of the posterior interradius, close to the margin of the right posterior groove. It is clearly seen in specimen A (Pl. X, Figs. 1 & 7) and B (Pl. XI, Figs. 1 & 2), and indeed can always be recognized whenever that portion of the test is plainly exposed. Its normal appearance is that of a small, slightly curved slit, approximately parallel to the right posterior ray. Its length is 1·1 mm. in A, 1·5 mm. in B. It widens slightly towards its adoral end, deepening at the same time, and becoming darkened with matrix, an appearance that indicates an oblique passage of the canal through the test. Specimen B shows the margin of the slit raised in a rounded rim, well defined at the adoral end and along the right side, but broken up into lobes on the other side. The slit is contained in two plates, and crosses the suture between them at right angles. The actual canal is only in the adoral of these two plates, and it may be that this plate is homologous with the interradial elements formed by the fusion of the peristomial floor-plates; but all the plates in this region are so closely united that the sutures are hard to trace. The tract of the adoral plate between the rim of the hydropore and the rounded margin of the peristomial floor-plates bears, in specimen B, about fifteen minute, closely-set pustules. Spinelets, if attached to these, would have provided a filter for the inflowing water.

Specimen E 15930 seems to show a slight branching of the slit, such as occurs during ontogeny in the very earliest stages of the folding that forms the madreporite of a recent Echinoid or Asteroid. Such branching increases the ciliated area by which the water-current is driven. The hydropore was not mentioned by E. Billings at any time, but his restored figure (1854, Fig. 10) shows that he observed something in the region where we now know it to occur.

The Under or Adapical face has been exposed by patient preparation in specimen A (Pl. X, Fig. 3), but is better shown in specimen C (Plate XIII). It is bounded by the distal halves of the four sinistrally curved radial grooves, which, as seen from below, of course appear dextral or solar. Their ends are quite definite, as described above (Text-fig. 4); when Plate X was drawn, some twelve years ago, they were still obscured by matrix, which has since been removed. The concave space included by these may, as in *E. buchianus*, be divided into three regions: the Peripheral Area, the Frame, and the Central Area.

The Peripheral Area is formed by a ring of plates serially homologous with the interradials of the upper face, and, in specimen A, connected with them by a single row of small plates passing between the rays. These peripheral plates of the under face are a little smaller than the majority of the interradials, and form, in specimens A and C, a single row, occasionally doubled, bordering the rays. In E 16173 (*E. levis*) these plates are relatively smaller than in A and C, and occupy a relatively wider belt, so that on both counts they are more numerous; they differ further in being more distinctly of two sizes, namely, larger plates with smaller ones surrounding or intercalated between them.

The Frame is a ring of larger and thicker plates (see the section, Pl. X, Fig. 9), the number of which appears to have been twelve in C,



Herring photo. London Stereoscopic Co.

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and probably the same number, not more, in A. In *E. buchianus* eleven such plates were counted, but the general shape and arrangement are the same in the two species. The inner margin of each frame-plate in *E. bigsbyi* is straight or concave, not convex as in *E. buchianus*. I have not observed on them any sign of tubercles or pustules, such as appear to have existed in *E. buchianus*.

The Central Area, in all specimens where any portion of it can be seen, is darker in colour and irregularly wrinkled (Pl. X, Fig. 11). It was doubtless covered by a flexible integument, filled with minute plates, which it has been possible to observe, though not clearly to photograph, in some tracts of specimen C (Plate XIII) and in E 16172 and E 15930. This scaly skin was attached to the frame-plates, and may as a rule have spread over them to some extent, especially at the sutures between them. The minute plates were tangentially elongate, and when closely pressed together, as in the folds, tend to project and to imbricate.

The adapical face of E 15930 (Pl. XIV, Fig. 1) differs from that of all other specimens observed in the apparent absence of a frame: the plated integument seems to stretch right up to the peripherals. In the region that should be occupied by the frame there are, however, appearances as though the integument had been thrown into raised circular or crescentic folds, each bounding a strongly pustulate floor. It may be that this floor is formed by the fusion of small plates, or that it indicates a frame-plate underlying the plated integument.

In cleaning away the matrix, it was peculiarly interesting to discover in these species the lobed central evagination, which I first made known in *E. buchianus*. Its pentagonal shape is not so obvious here. In A it is roughly triangular, with a short base in the left anterior interradius, and two long sides directed to a distinctly folded apex in the right posterior radius. One of these sides may be regarded as containing the lobes of the right anterior and right posterior interradii, and the other those of the posterior and left posterior interradii. In C (Plate XIII) the irregular lobate edge of the posterior half of this evagination is clearly seen, and we are perhaps justified in distinguishing the lobes of the three posterior interradii.

Prolonged preparation and repeated examination of the area surrounded by the lobes in A, C, and E 16172, have convinced me that there was no central opening of a permanent nature, such as E. Billings mentioned as apparently present (1854, p. 272). Neither is there evidence for pores of any kind in any part of the adapical face. It is perhaps hardly necessary to add that there is no sign of any stem or root, unless the central lobed region be regarded as in some sense the homologue of a stem.

Discussion of the physiological and morphological meaning of the structures herein described is reserved until, in a forthcoming Study, the structure of *Steganoblastus* shall have been redescribed. At this point, however, the distinctive features of the genus *Edrioaster* and of its four known species may be resumed in the following diagnoses.

Family EDRIOASTERIDÆ.

Edrioasteroidea with a theca composed of separate and relatively thin plates, and apparently without permanent attachment; with a subvective skeleton partly visible in apical aspect, and composed of floor-plates and movable cover-plates, having pores between the floor-plates; interradials of oral face continuous with those of apical face; central area of apical face covered with more flexible integument, bearing smaller plates; a hydropore (probably always) pierces an adoral interradial of the posterior interradius.

The genera are *Edrioaster* E. Billings, 1858; *Aesiocystis* Miller and Gurley, 1894; *Dinocystis* Bather, 1898; *Lebetodiscus* Bather, 1908.

Aesiocystis comprises a single species, *A. priscus*, based on four imperfect specimens from the Trenton Group of Mercer Co., Ky. (Bull. Illinois State Mus. Nat. Hist., No. 5, p. 13, pl. ii). The genus was placed by its authors in the family Hemicystidæ, but their description and figures show that it was almost certainly an Edrioasterid; indeed, my chief doubt is whether the species was not actually an *Edrioaster*.

Edrioaster.

An Edrioasterid with pores of subvective groove within the tract protected by cover-plates; with interradials all tessellate and separated from the central apical region by a frame of stouter plates; on the apical face the peripheral plates are variable in size but not minute, the central plates are minute and tend to imbricate.

Edrioaster bigsbyi E. Billings.

An *Edrioaster* with height of theca about one-third of diameter, periphery roughly circular; with rays clearly raised above general surface, and floor-plates clearly demarcated from interradials; rays I, II, III, IV have a contrasolar curve, ray V a solar curve, ray IV bends upwards within r. ant. interradius; interradials of oral face bear coarse, sparse pustules.

This is the genotype.

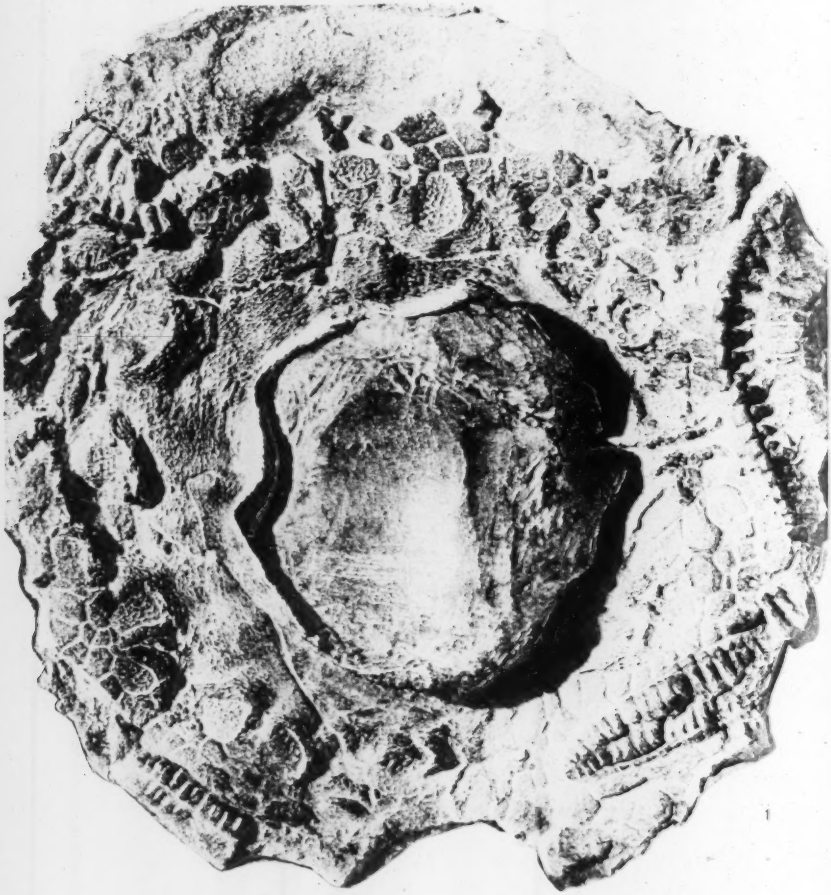
Edrioaster buchianus E. Forbes sp.

An *Edrioaster* with height of theca one-half the diameter or more, periphery sub-pentagonal with convex interradii; with rays apparently not raised above general surface, but with floor-plates clearly demarcated from interradials; rays all have a solar curve; interradials slightly pustulate?

Edrioaster saratogensis Ruedemann.

An *Edrioaster* with depressed theca (height probably about one-fourth diameter), periphery sub-circular to sub-pentagonal with convex interradii; with rays clearly raised above general surface, and floor-plates not regularly demarcated from interradials; rays all have a solar curve; interradials relatively few, and all, as well as cover-plates, densely and finely granulose.

This diagnosis is based partly on the description and figures of Dr. Ruedemann (1912, Bull. N.Y. State Mus., No. 162, p. 86, pl. iii), partly on squeezes which he was so kind as to send me. Dr. Ruedemann, apparently being acquainted with none of my previously published



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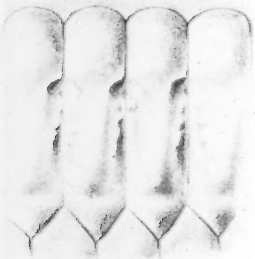

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work on *Edrioaster*, naturally found difficulty in describing his imperfectly preserved specimens. The subvective skeleton has the normal *Edrioaster* structure, and the so-called 'subambulacral plates' marked '*a*' in pl. iii, fig. 4, are incorrectly drawn. The absence of evidence for a contrasolar ray has already been alluded to (p. 122). The 'triangular oral plates' are presumably the interradial elements of the mouth-frame. The cover-plates slope from their outer margins towards the oral pole; those pushed into the groove tend to imbricate adorally.

The original specimens came from sandstone in the Snake Hill shales of Saratoga Co., N.Y. These beds are supposed to lie just above the Basal Trenton, and below the *Prasopora* zone. The species is therefore the oldest of the four here discussed.

EDRIOASTER LEVIS n.sp.

An *Edrioaster* with height of theca about one-third of diameter, periphery roughly circular; with rays scarcely raised above general surface, and floor-plates not clearly demarcated from interradials; rays all have a solar curve; interradials faintly scrobiculate, not pustulate.

Holotype, Brit. Mus. E 15900.

EXPLANATION OF PLATES.

PLATE XIII.

Edrioaster bigsbyi. The adapical face of specimen C, of the Canadian Geological Survey, showing the peripheral portions of rays I–V, the eleven large frame-plates, and the lobed evagination of the central integument, the small plates of which are not clearly seen. × 3 diam.

PLATE XIV.

Edrioaster bigsbyi.

Fig. 1. The adapical face of E 15930, with same orientation as Plate XIII. The minute plates of the central integument are well shown. In the place of the frame are the circular elevations of this integument described on p. 169. Photographed by Mr. H. G. Herring. × 3 diam.

Fig. 2. Part of the circumoral region of the test of E 16172, seen from the interior, as described on p. 165. Drawn by Mr. W. G. Browning. × 3 diam.

Fig. 3. Some floor-plates of E 16172, showing the ridges that lead from the peripodia to the perradial channel. Drawn by Mr. G. C. Chubb. × 10 diam.

V.—SOME NOTES ON A DEEP BORING THROUGH THE CHALK OF DENMARK.

By H. FABER, F.C.S., and W. K. SPENCER, M.A., F.G.S.

EARLY in the year 1913 the Copenhagen Museum of Mineralogy and Geology issued a report[1] upon a most interesting deep boring in the Chalk at Gröndal, just outside Copenhagen. The results are so striking in respect to the thickness of chalk passed through that it appears desirable to bring them before the notice of English geologists. The estimates of the thickness of the English Chalk

[1] *Dybdeboring ved København, 1894-1907*, ved E. P. Bonnesen, O. B. Böggild, og J. P. J. Ravn, Copenhagen, 1913.

which are considered to be the most reliable are those given by Rowe from measurements of the various zones in the Isle of Wight and Dorset. These are approximately as follows:—

	Isle of Wight. feet.
Zone of *Belemnitella mucronata* . . .	475
,, *Actinocamax quadratus* . . .	343
,, *Marsupites*	47
,, *Uintacrinus*	34
,, *Micraster cor-anguinum* . . .	310
,, *M. cor-testudinarium* . . .	52
,, *Holaster planus*	60
,, *Terebratula gracilis* . . .	65
,, *Rhynchonella Cuvieri* . . .	84
	1,470

Further north a much greater thickness of the two upper zones is suspected. Thus Rowe estimates that at least 400 feet of 'quadratus' chalk occur in Yorkshire. This cannot be the full thickness, for, although *Actinocamax granulatus* is abundant, specimens of *A. quadratus*, the Belemnite characteristic of the upper part of the zone, have only been met with in the very highest beds. We also know that 'mucronata' chalk of a higher horizon than that found in either the Isle of Wight or Dorset is found in Norfolk, and that higher horizons are represented on the Continent. Nevertheless, nobody could have expected that results at all comparable with those given in the report would be obtained.

The boring was taken through 2,742 feet, and yet the bottom of the Chalk was not reached. Indeed, Ravn, from the fossil evidence, regards the boring as only reaching the level of the zone of *A. quadratus*. His table reads as follows:—

	feet.
Alluvial and diluvial	34
The Danian Chalk	86
Upper 'Mucronata' Chalk . .	about 1,580
Middle and Lower 'Mucronata' Chalk	about 400
'Quadratus' Chalk . . .	at least 642

If this table is correct it is obvious that the 'mucronata' chalk may be of a greater thickness than the whole of the remaining Chalk, and should therefore be capable of much more minute subdivision than has hitherto been attempted.

The following paragraphs give some general account of the methods adopted and the lithological and palæontological evidence as to the succession of the strata. It will be seen that the investigators have good evidence to offer in support of their conclusions.

History of the Boring.

The boring was initiated as an attempt on the part of the Frederiksberg District Council to obtain water. A depth of 230 feet was reached, and then the search for water was abandoned. The engineer, Marius Knudsen, offered, however, to proceed with the boring in the interest of science at a very reduced cost, and the late Professor Ussing was successful in obtaining a grant from the

Carlsberg Fund in order that the work might be undertaken. The Frederiksberg District Council promised to pay for the coal used. The idea was to bore completely through the chalk to the underlying strata, which, it was estimated, would be reached at a depth of 1,600 feet.

The American method of boring was employed. A heavy broad chisel was used, fixed on a heavy iron rod suspended by means of two steel links from a stout manilla rope. The apparatus was worked up and down by machinery in such a way that the engineer could tell how the chisel worked and could keep it turning round. When enough material had been cut loose it was brought up by letting down a 'sand pump' or syringe and filling this several times with the chalk suspended in water. Of course, the material became very much pounded up. Large pieces were sometimes obtained either by first boring a small hole and then chipping the chalk into the cavity thus obtained or, when the chisel failed to turn and therefore made a narrow cut, by cutting open with a ring-shaped chisel.

The boring was 24 inches in diameter for the first 90 feet. It was then reduced to 15 inches. When, in May, 1896, a depth of 1,222 feet was reached, 12 in. tubing of soft steel in 8 ft. lengths was let down nearly the whole depth (for 1,211 feet), and the boring was continued with a 12 in. chisel. In September, 1901, a depth of 1,577 feet was reached. From this point a 9 in. chisel was used. In 1902 the borehole between 1,577 ft. and 1,630 feet was widened to 12 inches, and by this means larger pieces of rock with fairly good fossils were obtained. An attempt to continue the steel tubing downwards was not successful. A depth of 2,742 feet (860·6 metres) was reached in March, 1907. The boring was still in chalk, and beyond this depth the American method of boring was impracticable. The borehole, however, is kept open for a possible later extension by 'diamond boring'.

The boring took a longer time than had been expected, as either flint or very stiff clayish marl caused great difficulties. Grant after grant was generously voted by the Carlsberg Fund. The State also contributed. The total amount expended was about £8,100.

It was found that the temperature increased 1° C. for each 46·1 metres, and that the increase of temperature was quite uniform. Observations were made for each 50 metres.

The Rocks and Fossils of the Strata through which the Boring passed.

The value of the evidence as to the thickness of the strata passed through depends largely upon proof that the strata were horizontal. If the beds were at all steeply inclined entirely fallacious results might, of course, be obtained. We shall see that both the lithological and palæontological evidence offers strong proof that the beds were almost, if not quite, horizontal. It may be mentioned, in passing, that the continuation of the Danian and 'mucronata' beds across the Sound into Sweden is in itself good *prima facie* evidence that there are no steep folds in the Chalk in this immediate neighbourhood.

The rocks show a regular succession in their lithological features. The 'Saltholmskalk' is met with for 86 feet. Below that 880 feet

of soft chalk occur. In this there are many layers of flint. Down to 400 feet the flints are mostly black, from 400 feet to 900 feet they are a white opal. The flint layers gradually disappear. The soft chalk is succeeded by chalk with alternating soft and hard layers (1,000–1,600 feet). From 1,600 to 1,700 feet there is a hard limestone graduating to marl. From 1,700 to 2,742 feet the rock is a marlstone with layers of light and dark marl, which increase in frequency, darkness, and proportionate content of sand as the boring deepens.

The mineral analysis of the material suggests from the proportion of sand to that of calcium carbonate that there was on the whole a deepening of the water in which the rocks were laid down, but the depression was not quite continuous. There appears to have been a slight elevation during the period represented by the rocks met with from about 1,850 to 2,250 feet, followed again by a lowering of the floor of the sea.

That this regular succession is accompanied by horizontal bedding is shown by the larger pieces of chalk obtained from the depths 1,600–1,630 feet. At these depths the chalk contained thin layers of clay, and the chisel-marks were always at right angles to the layers. Similar evidence of horizontal layers was obtained from lower depths.

The palæontological evidence suggests that the following strata are met with:—

0–4 feet	Alluvium.
4–34 feet	Diluvium.
34–120 feet Saltholmskalk	Danian.
120–923 feet Skrivekridt with Flint	Upper 'Mucronata' Chalk.
923–1,700 feet (about) Chalk without Flint	Upper 'Mucronata' Chalk.
1,700–2,742 feet Grey Marl with Sand	Middle and Lower 'Mucronata' Chalk.
	'Quadratus' Chalk.

One of the first objections which may occur to the reader is that there is no certainty of origin of any of the fossils. The chisel in being lowered might chip off a fossil at any depth from the sides of the boring, and this would fall to the bottom and be listed as found at a much lower horizon than that to which it really belonged. The lining of the first 1,200 feet with steel tubes prevented, at any rate, fossils from these depths (and the point is vital to the evidence) from being mixed with the lower fauna.

The great thickness of the 'upper mucronata' is of course very surprising. No one would have imagined that the 'mucronata' chalk could have exceeded 500 feet in thickness, and it is necessary therefore to examine very carefully the evidence upon which the above table is based.

The Skrivekridt with flints contained the following 'mucronata' fossils: *Terebratulina gracilis*, v. Schloth., sp. (270 feet); *Cidaris baltica* (Schlüt.) (780 feet). Fragments which appeared to be *Lima denticulata*, Nilss., sp., and *Scaphites constrictus*, Sow., sp., were found at depths of 330 and 511 feet respectively.

The chalk without flints (923–1,700 feet) contained *Scalpellum cretæ*, Stp. (1,274 feet), and *Serpula conica*, v. Hag. (1,280–1,360 feet).

Fragments which appeared to be those of *Sc. constrictus* were found at the depth of 1,580–1,590 feet. About this same depth, where it will be remembered large lumps of chalk were obtained, there occurred *Scalpellum cretæ*, *Membranipora crassa*, Marss., and a *Terebratulina* cf. *ornata*, Roem., all of which suggest a Skrivekridt fauna. The marlstone (1,700–2,742 feet) yielded *Metopaster tumidus*, Spencer, var. *radiatus*, Spencer (1,920 feet), and *Metopaster undulatus*, Spencer (2,015–2,070 feet). Both these Asteroids indicate a horizon not lower than the 'middle mucronata'. *Pollicipes fallax*, Darw. (2,070 feet), and *Crania antiqua*, Defr. (2,380 feet), suggest according to the authors a 'mucronata' or 'quadratus' horizon for the chalk near the bottom of the boring. The occurrence of *Belemnitella lanceolata*, v. Schloth., sp., at a depth of 2,648 feet seems to indicate, together with the preceding evidence, that the boring had now definitely entered 'quadratus' chalk.

Besides this positive evidence it appears to the authors of these notes that the fact that no plates of *Marsupites* and *Uintacrinus* were found is good proof that these horizons were not reached.

Ravn, in a general summary of the results obtained, states that Moberg and Hennig in studying the Chalk of Scania find that the sea broke over South Sweden in the Lower Senonian. The sea increased in depth through the 'quadratus' and into the 'mucronata' period. It then receded for a time (about the 'middle mucronata') and afterwards increased in depth more quickly than before.

These observations support the evidence from the boring in Denmark. The analyses of the material from the boring (on samples from each 50 feet) show that the marly chalk from the lowest point is fairly rich in sandy particles, and that these particles, which imply the proximity to the coast, decrease in quantity higher up. This is followed by a definite increase in the proportion of sand at a depth of about 2,250 feet, until at 2,100 feet there is a definite layer of sand. The proportion of sand a second time decreases until we reach a pure white chalk. This seems to prove that the lowest strata reached by the boring were formed in a somewhat shallow sea, which gradually increased in depth, again became more shallow, and finally deepened rapidly.

Ravn thinks that if the boring could be continued further the bore-hole would soon find the shallow-water Lower Senonian deposits which form the base of the Chalk in Denmark.

Conclusions.

The authors of the report are to be highly congratulated on the careful manner in which they conducted their investigations, and on the convincing detail which they carefully set out. All the fossils were submitted to palæontologists familiar with the group which they investigated. Elaborate chemical analyses were undertaken by Professor Billmann, and these are of great help to the argument. Records of the increase of temperature as the boring proceeded downward were also made.

The results obtained add interest to investigations upon the English 'mucronata', and especially the 'mucronata' of Norfolk. Although

the Trimingham Chalk has been shown to be of higher horizon than that found in any other English locality, no one has yet been able to determine its exact relationship to other English Chalk in situ. A boring at Mundesley or at some other point on the eastern coast appears to be necessary if it is desired to make our knowledge of the English Chalk complete. It is to be earnestly hoped that some such boring will be undertaken at no very distant date.

REVIEWS.

I.—Cambridge County Geographies.

Merionethshire. By A. Morris, F. R. Hist. Soc. Small 8vo; pp. 166, with a Physical and a Geological Map, and 48 illustrations in the text; cloth boards. Cambridge University Press, 1913. 1*s.* 6*d.* each.

MERIONETHSHIRE is a maritime county of North Wales, open to Cardigan Bay on its western side, and enclosed north, east, and south by the counties of Carnarvon, Denbigh, Montgomery, and Cardigan respectively. It is more mountainous than any other part of North Wales, except perhaps Carnarvonshire. Its deep and secluded valleys, with the ruggedness and variety of its elevated districts, give it a particular charm and interest. The varied panoramic views from its heights surpass anything to be seen in Wales.

The nature of the rocks enables a portion of the country to be devoted to slate-quarrying. It is the only county in Wales in which gold has been found (at Dolgelly) in quantities sufficient to pay for working. (See Geol. Mag. 1865, p. 558.)

No isolated, solitary peak of the Welsh mountains shows such a wreck of stone as Cader Idris. With an elevation of 2,927 feet above the sea-level, it marks the starting-point from which a long chain of primitive mountains extends in a north-east direction to the Berwyns and on to the borders of Shropshire. (p. 13.)

The Harlech Dome, as it is called by geologists, is a large, irregularly-oval track, lying between Dolgelly and Harlech, and ranging northward to Maentwrog. It is occupied by unfossiliferous grits, and purple and green slates. It holds a very important place in the physical features of North Wales, being the site of the great Merionethshire anticlinal, in which the rocks dip in opposite directions like the roof of a house. On the flanks of these sloping rocks the fossiliferous flags and grits of the Lower Cambrian Series are observed to rest. (p. 35.)

The Lingula Flags are divided into three groups—the Maentwrog, the Festiniog, and the Dolgelly Groups. The first is characterized by its jointed dark-blue ferruginous slates, the second by hard micaceous flags, and the third by soft, black slate, which shows a black streak when scratched. (p. 35.)

The range between the Rivers Eden and the Mawddach in the neighbourhood of Dolmelynllyn has always been famous for its fossils.

The Ordovician occupies the largest area in North Wales. It spreads in numerous undulations around the towns of Bala and Corwen; it

forms the main construction of the Arenigs, the Aran, the Gader group, and the Berwyns; and in it we have the Festiniog, Corris, Abergynolwyn, and Aberllefenni slate quarries.

The Silurian Series stretches from near Bala to the eastern borders of the county. The term 'Bala Beds' is given to these rocks all over Wales, because they are best developed from Dinas Mawddwy by Bala to Bettws-y-Coed. (p. 36.)

The largest 'fault' in the British Isles cuts through the middle of Bala Lake from south-west to north-east. Professor Sir Andrew Ramsay has made the Bala Lake historic by his description of its glacial origin; indeed, the whole region is classic ground to the geologist.

In addition to its scenery (unsurpassed by any other county in Wales) Merionethshire is full of interesting relics and antiquities. It is rich in churches, abbeys, castles, manor houses, Roman remains, whilst its survivals of Welsh manners, habits, and customs exceed all the other counties of Wales and would alone suffice to attract the intelligent visitor.

Mr. Morris's handy County Geography, from its small size and completeness, will be found well suited for a pocket companion.

II.—Text-book of Petrology, Volume I.

The Petrology of the Igneous Rocks. By F. H. Hatch, Ph.D. 7th edition, revised. Cr. 8vo; pp. xxiv + 454, with 154 figures. London: George Allen & Co., Ltd., 1914. Price 7*s.* 6*d.* net.

LAST year Dr. Hatch and Mr. R. H. Rastall published the *Petrology of the Sedimentary Rocks*, styling it "Text-book of Petrology, Volume II". It was then understood that a volume uniform with this and dealing with igneous rocks would appear shortly: this volume is now before us in the form of a revised edition of Dr. Hatch's "Text-book of Petrology", first published in 1891, but almost entirely rewritten in 1909. The two volumes form a textbook which claims to constitute a brief but complete summary of the whole science of rocks.

In revising the book the author has had occasion to write two new chapters on Pyroclastic Rocks and on the metamorphic derivatives of igneous rocks, the latter really forming a supplement to the more general treatment of metamorphism found in the *Petrology of the Sedimentary Rocks*. Here the metamorphosed igneous rocks are classed as: plutonic gneisses, schists derived from hypabyssal, from volcanic, and from pyroclastic rocks; such a classification can only be applied when the origin of the metamorphic rocks can be ascertained. For the subdivisions of the plutonic gneisses the five groups suggested by Dr. Teall in 1907 are used. These groups are based primarily on mineralogical constituents and to a subordinate extent on structure, and, in the present state of our knowledge, they form most useful divisions. By using the mode of origin as a basis of classification in this chapter Dr. Hatch has compelled himself to omit some interesting types of metamorphic rocks which were not dealt with under the sedimentary rocks. Thus we look in vain for any account of the granulites, though the more basic pyroxene-granulites appear under plutonic gneisses.

As regards the rest of the book, it is practically a reprint, with a few additions and corrections, of the fifth edition (1909) of the "Text-book of Petrology". The fact that this book has run through so many editions is sufficient proof of its excellence, and it is so well known that it is quite unnecessary to call attention to its merits. The additions are very few: the subject of dynamic metamorphism is treated rather more fully, and a table of mean refractive indices of minerals has been added. Birefringence is still stated as 'weak', 'moderate', or 'strong', though it has been pointed out that to give the actual values of the greatest and least refractive indices would be the more satisfactory procedure, and would make this part of the book far more useful.

The classification of igneous rocks which was introduced in 1909 has been retained and, in the case of the gabbros, a further subdivision into a labradorite and an anorthite series has been suggested. Objection has been raised to Dr. Hatch's classification on the ground that it is neither consistently mineralogical nor consistently chemical. However, no classification is free from such objections, and Dr. Hatch's scheme is one which has been found to have many advantages.

In revising the descriptive part of the book the author has not everywhere succeeded in including the results of most recent work—in fact, there are very few references to any work published since 1910. Thus borolanite is still classed with the alkali-gabbros, though in a recent paper Dr. Shand has pointed out its affinities with the syenites and has described new rock-types associated with it. 'Spilosite' on p. 29 is obviously a misprint for 'spilite', but this is the only mention made of this rather important group of rocks, and no reference is made to the important paper by Dewey & Flett, published in this journal in 1911.

The printing is done very well, and the book is vastly improved by the reproductions of a large number of excellent photographs by the Geological Survey and by Dr. H. H. Thomas.

III.—Hints on Collecting Geological Information and Specimens. By G. W. Grabham and Stanley C. Dunn. pp. 24. Khartoum: published by the Sudan Government. Price 6*d*.

THIS little book is the work of the two geologists who constitute the personnel of the Geological Survey of the Anglo-Egyptian Sudan. When the task of surveying an area of nearly a million square miles is allotted to so small a staff of professional geologists progress must necessarily be slow, and it has been thought desirable to enlist the services of other Government officials to furnish the Survey with geological information concerning the districts its members are not able to visit. These directions have accordingly been issued to afford some guidance as to the information to be furnished and the specimens to be collected. The latter subject might perhaps have been more fully treated, for a good collection representing the rocks, minerals, and fossils of an area is more likely to be of real value than attempts at geological description by those who have an imperfect knowledge of geological principles and little or no experience in field work. Owing to the circumstances of the country special

attention is given to water supply, and the authors insist on the importance of recording the geological and hydrographical data afforded by wells. The book concludes with tables describing the characters of the commoner minerals and rocks.

The "Hints" are written in simple language, and should be of value, not only for their immediate purpose, but also in spreading an interest in geology amongst those who have such magnificent opportunities of doing good scientific work if they will only make themselves sufficiently acquainted with the subject.

IV.—Brief Notices.

1. New Zealand. Mines Department (Geological Survey Branch). Seventh Annual Report, June, 1913. pp. 115–42, with 3 maps.—This contains a general summary of the progress of the Survey and six special reports, dealing with economic geology, by P. G. Morgan and J. Allan Thomson. A report by J. A. Bartrum, on the geology of the Te Puke District, Hauraki District, Auckland, contains notes on the economic and general geology and on the petrography of the area. Some interesting hypersthene-bearing rhyolites and andesites are described.

List of the Minerals of New Zealand. By P. G. Morgan and J. A. Bartrum. pp. 32. 1913.—As it is intended to publish a handbook to the minerals of New Zealand, this list is to be regarded as provisional; it has been compiled at very short notice to accompany the "Catalogue and Description of Exhibits of the Mines Department" prepared for the Auckland Exhibition. Even in this incomplete state this publication will be of much value. It contains an alphabetical list of minerals and of materials of economic importance, with the localities at which each occurs and abundant references to the literature.

2. Miocene Ostracoda.—Dr. Bela Zalanyi has issued in the Mitt. Jahrb. k. Ungarisch. geol. Reichsanstalt, vol. xxi, pt. iv, pp. 87–152, pls. v–ix, a most valuable paper on the Miocene Ostracoda of Hungary. Forty-one species are described, of which twenty-five are new to Hungary and twelve are new to science. Dr. Zalanyi has given large and excellent figures, and has paid especial attention to the hinge and muscle-spots of these small Crustacea, and the paper should be of much interest and service to students of European forms.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *February* 4, 1914.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Lithology and Composition of Durham Magnesian Limestones." By Charles Taylor Trenchmann, B.Sc., F.G.S.

The present communication is the result of a somewhat close inquiry into the composition and lithology of the Magnesian Limestones of Durham in all their divisions and conditions of alteration.

More than ninety analyses were carried out, of which seventy-eight are herewith presented. Several of the rocks were sliced and stained with Lemberg's solution.

Care was exercised, before a sample was taken, to ascertain the degree of alteration, through segregation or otherwise, which the rock had suffered.

The results show that the formation maintains, generally speaking, a highly dolomitic character, with certain important exceptions. Those portions which show a calcareous composition may be regarded as the result of one of three main causes :—

(1) Original conditions of sedimentation, during which dolomitic deposition or processes of secondary dolomitization were temporarily arrested. Calcareous beds with a Brachiopod fauna are extensively developed near the base of the Lower Limestone in the south-western portion of the area.

(2) Escape from secondary dolomitization. Portions of the Shell Limestone reef, notably at Tunstall Hill, from causes only partly explicable, have escaped conversion into dolomite.

(3) Calcareous segregation, penecontemporaneous with or subsequent to deposition.

The paper is intended to be purely a record of observed facts, and no theoretical questions are raised; but internal evidence on several points is brought forward in favour of the view of direct sedimentation of dolomite from the waters of the Permian sea. The view that the bedded dolomites are the result of secondary dolomitization of calcareous organisms is a very improbable one. The question of the secondary dolomitization of the Shell Limestone reef is discussed.

The dedolomitization of the formation is due to the mechanical washing-away of powdery dolomitic material through the interstices of the rock. The nature of this material was investigated chemically and microscopically. It results from the withdrawal of interstitial calcite, both through former processes of segregation and under existing conditions through the action of percolating water.

No evidence of any leaching-out of magnesium carbonate from the rock was found. Dolomite, even in a fine state of division, is almost insoluble relatively to calcite, but a question certainly arises as to whether such was also the case in earlier periods, in presence of saturated or supersaturated solutions of sulphates.

The nature and distribution of the true cellular rock are discussed, and modes of origin are suggested.

Some general deductions are drawn from evidence of insoluble residues.

Finally, a summary of the general conditions of deposition of the Durham Permian, from the Marl Slate upwards to the Salt Measures, is given, so far as seems legitimately deducible from the available facts.

2. "On the Occurrence of a Giant Dragon-fly in the Radstock Coal-measures." By Herbert Bolton, M.Sc., F.R.S.E., F.G.S., Reader in Palæontology in the University of Bristol.

The writer describes the structure of a wing-fragment found some years ago upon the Tyning waste-heap at Radstock Colliery (Somerset), by Dr. E. A. Newell Arber, F.G.S.

The fragment consists of the proximal third of a left fore-wing. It is remarkable for its size, being 64 mm. long and 40 mm. broad, the complete wing having an estimated length of 190 mm., or 7·5 inches; the whole insect (with wings extended) must have had a span of over 400 mm., or 16 inches.

The anterior wing-margin is strongly tuberculated proximally, and more distally bears a closely-set series of pointed spines directed outwards towards the wing-apex. The hinder wing-margin is also spinous, the spines being a little way inwards from the edge, and possibly serving to interlock the fore and hind wings during flight. The radial and median veins are missing, but the characters of the costa and subcosta on the anterior portion of the wing, and of the cubital and anal veins on the hinder part, show clearly the close relationship of the insect to the members of the family Meganeuridæ, a group including the enormous *Meganeura monyi*, Brongniart, from the Stephanian of Commentry (Allier). The wing is referred to the genus *Meganeura* as a new species. The precise horizon from which the shale was derived cannot be determined, as the Tyning waste-heap has received material from five different collieries.

ANNUAL GENERAL MEETING.

2. *February* 20, 1914.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The Reports of the Council and of the Library Committee were read. It was stated that of the 65 Fellows elected in 1913 (2 more than in 1912), 48 paid their admission fees before the end of that year, making, with 16 previously elected Fellows, a total accession of 64 in the course of 1913. During the same period the losses by death, resignation, and removal amounted to 43 (9 less than in 1912), the actual increase in the number of Fellows being, therefore, 21 (as compared with an increase of 5 in 1912). The total number of Fellows on December 31, 1913, was 1,308.

The Balance-sheet for that year showed receipts to the amount of £3,367 8*s.* 11*d.* (excluding the balance of £641 2*s.* 3*d.* brought forward from 1912), and an expenditure of £3,137 12*s.* 1*d.*

The Reports having been received, the President presented the Wollaston Medal to Dr. John Edward Marr, F.R.S., addressing him as follows:—

Dr. MARR,—I am pleased that it has fallen to my lot to address, on such an occasion as this, one with whom I have so long enjoyed an intimate friendship, and by whose work I have profited so greatly.

At the conclusion of a distinguished University career you commenced, in 1878, a series of investigations, through which your name will always be associated with the Lower Palæozoic rocks. Concentrating your attention first on the zoning of the strata between the Coniston Limestone and the Coniston Grits in the Lake District, you continued the work of Hughes, Aveline, and Salter, established a classification, and discussed the division between the Silurian and those Cambrian subdivisions of Sedgwick which are now known as Ordovician. In 1880 you carried your researches into North Wales, and instituted a comparison of the sequence as there developed with that of the Lake District. During the same year you laid before this Society the results

of your visit to Bohemia, where you had been commissioned by the University of Cambridge to investigate the 'Cambrian' and Silurian sequences, with special reference to the boundary between them. In carrying this work to a successful issue, you were not only able to institute a comparison of the Bohemian and British developments, but incidentally to show that there existed serious objections to the acceptance of Barrande's 'colonies', both on palæontological and on stratigraphical grounds. Extending your investigations to Scandinavia, you proved that Sedgwick's classification was applicable in that country also, and that the principal stratigraphical and physical break occurred at the base of the equivalents of our May Hill Beds.

Your ripe experience of the Lower Palæozoic rocks was then turned to account in South Wales, where, in collaboration with the late T. Roberts, you undertook the task of subdividing the groups which had been outlined by the early surveyors. Your success in carrying out this programme may be judged when I say that during the recent re-examination of the district by the Geological Survey all the subdivisions made by you and your colleague in 1885 were adopted, and will be utilized in the forthcoming maps and memoirs.

Returning later to the scene of your earliest labours, with the late H. A. Nicholson as your colleague, you completed further palæontological zoning in the Stockdale Shales, and proved by precise field-work that an appearance of unconformity between the lowest zone and the Ashgill Shales was defective and due to strike-faulting.

In 1891, with Dr. A. Harker, you made a detailed study of the effects produced by the intrusion of the Shap Granite upon the surrounding rocks. Your familiarity with the Lake District strata, combined with the petrographical skill of your colleague, enabled you jointly to produce a classic account of the phenomena of contact-metamorphism, as exhibited in calcareous and siliceous sediments and in igneous rocks.

Of late years physiographical problems have engaged your attention, and as a result of your observations on mountain-lakes it may be expected that a wiser caution will be exercised than heretofore in identifying rock-basins as such and in postulating glacial erosion for tarns.

But it is not only this long record of original research, of necessity incompletely outlined, which the Council have had in mind in making this award. They remember that since 1880 you have been continuously engaged at your old University in assisting the Woodwardian Professor to create the foremost school of geology in Britain. The influence of your teaching in the lecture-room, in the field, and as conveyed by your textbooks has extended farther than perhaps you yourself realize. A happy combination of the power to make original research with a facility for imparting your knowledge has enabled you to exercise a profound influence on the growth of our science.

It is, therefore, with great satisfaction that I hand to you, on behalf of the Council, the highest honour which it is in their power to bestow—the Wollaston Medal.

Dr. Marr, in reply, said :—

Mr. President,—I feel that the award of this Medal is due to a combination of a number of favourable circumstances.

I have been fortunate in having worked and published papers in conjunction with many geologists, including T. Roberts, Nicholson, Harker, Garwood, and Fearnsides. Two of them have, alas! passed away, and one of the great griefs of my life was the loss of that ardent geologist and genial companion, Alleyne Nicholson.

My long association with this Society as Officer and Member of Council has brought me into contact for many years with men from whom I could learn the results of the recent discoveries in our science.

I regard this award as made not only to myself but to the Cambridge School of Geology, and in speaking of this school would first bear tribute to the advantage of the teaching which I received in my undergraduate days from Professor Hughes and Professor Bonney. During the seventies a number of

brilliant geologists emerged from that school, of whom you, Sir, were one. I cannot help acknowledging also the benefits of the teaching in the field which I received from an Oxford man whom I have the honour of counting as a friend of over forty years' standing—Mr. Tiddeman.

I have, as you observed, for many years been myself a teacher in the Cambridge School, and here again have benefited from the ardour and enthusiasm of my pupils. Their cordial congratulations to me on receiving this award show that they, as well as I, appreciate the honour.

Before passing from the subject of Cambridge I must refer, Sir, to our old College. It is no doubt a satisfaction to you as to me to find the names of five members of St. John's enrolled in the lists of the Wollaston Medallists within the last twenty-five years.

I thank the Council most sincerely for the bestowal of this their highest award. There is, however, an honour which I should rank still higher, and that is the cordial approval which I feel that the Council and general body of Fellows would accord to one who did his utmost to serve the interests of the science and of the Geological Society to the end of his life. The desire to gain this approval will surely stimulate me to work in the future.

The President then presented the Murchison Medal to Mr. William Augustus Edmond Ussher, F.G.S., addressing him in the following words:—

Mr. USSHER,—For more than forty years, as a member of the staff of the Geological Survey, you devoted yourself whole-heartedly to the work entrusted to you. Though at one time or another you were engaged in various parts of England, the South-Western Counties are those with which your name is most closely associated. Indeed, among the many distinguished men who have laboured in Cornwall, Devon, and Somerset, you have done more than most to unravel the tangle of Palæozoic rocks and to classify the Newer Red rocks there exposed.

So long ago as 1875 you communicated your first paper on the Trias to this Society, and two years later you followed this up by a comparison of the Triassic development of the South-West of England with those of the Midlands and of Normandy.

At this time also you began to publish the results of those researches on the Palæozoic sequence which were destined to fill so large a part of your official career. Partly in association with the late A. Champernowne, and with help derived from the writings of De la Beche and other early workers in the same field, you proceeded with what seemed the almost hopeless task of interpreting the structure of the country and defining the limits of the Carboniferous rocks and of the Upper, Middle, and Lower Devonian groups. It is not possible for me, on this occasion, to trace the steps by which you reached your final conclusions. I can only refer to your published accounts in the Journal of this Society, in the Memoirs of the Geological Survey, and in the Transactions of the Devonshire Association, and assure you that the exceptional difficulty of the task which fell to you, involving as it did a bewildering complexity of structure, difficult palæontology, and for a time at least an inadequate topographical basis for your work, is recognized by all geologists. The Council desire to take this opportunity of testifying their appreciation of your efforts, and on their behalf I beg to hand you the Murchison Medal.

Mr. Ussher replied in the following words:—

Mr. President,—I sincerely thank you, the Council, and the Fellows of this Society for the honour thus conferred upon me and for the unanimity with which it has been bestowed. The work to which, Sir, you so flatteringly refer was done so long ago that this recognition is doubly grateful, as a convincing proof that my researches have not been forgotten.

My work among the New Red rocks of the South-Western Counties, begun in 1870 and completed in 1880, was inspected by my old chief, Sir Andrew Ramsay, who characterized it as "first-class work", a commendation most encouraging

at the time and still a highly prized remembrance. This work has not all been officially published, even now.

The discovery of the structure and succession of the Devonian rocks would have been effected by a dear friend of mine, the late A. Champernowne, but for his untimely death in 1886. In 1888–9 I was employed in endeavouring to reconcile the different versions of Champernowne's work, with a view to publication, and I made an earnest attempt to solve the doubts which Champernowne entertained as to the relative positions of certain members of his sequence. The solution of these problems led to the establishment of the true Devonian succession in South Devon, and to the correlation of the subdivisions with those of the Continent. In this work I have been greatly assisted by Continental geologists, among whom my old friend Professor Gosselet (a former recipient of the Murchison Medal) figures prominently. The tentative application of this succession to Cornwall in 1891 was proved to be substantially correct by the subsequent work of the Geological Survey.

In conclusion, Sir, allow me to renew the expression of my thanks for the honour conferred upon me.

In handing the Lyell Medal, awarded to Charles Stewart Middlemiss, B.A., to Sir Thomas H. Holland, K.C.I.E., for transmission to the recipient, the President addressed him as follows:—

Sir THOMAS HOLLAND,—During a service of more than thirty years on the Geological Survey of India, Mr. Middlemiss has done much to advance our knowledge of the geology of that country.

He was one of the first to apply modern microscopical methods to Indian problems, and by their use in dealing with palagonite-bearing traps and the phenomena of contact-metamorphism arising from the intrusion of the Himalayan central granite, was able to make important contributions to the science of petrography. We are indebted also to him for a great extension in our knowledge of the Archæan complex in the southern and south-eastern parts of the peninsula.

In his studies on tectonic geology in the Sub-Himalaya of Kumaon, the frontier district of Hazara, and the Salt Range of the Punjab he has displayed a marked originality, and his more recent work in Kashmir has done much to elucidate the pre-Tertiary geography of Gondwanaland. His investigations of the Bengal earthquake of 1885, and his elaborate analysis of the phenomena accompanying the disastrous Kangra shock in 1905, form valuable additions to seismological records. No less has applied geology benefited by his investigations on the stability of slopes in mountainous regions.

The papers in which Mr. Middlemiss has presented his results enrich the publications of the Geological Survey of India, not only by their scientific value, but by the literary charm of his pen and by the happy facility of his pencil.

In recognition of this great record of work, the result of single-hearted devotion to his duties, I ask you to forward to Mr. Middlemiss, on behalf of the Council, the Lyell Medal.

Sir Thomas Holland, in reply, said:—

It gives me special satisfaction in this way to represent my Service in acknowledging the honour bestowed on a colleague who, by his unselfish devotion to work and his gentle disposition, has so conspicuously earned the affectionate respect of every officer with whom he has worked.

You have referred, Sir, both judicially and judiciously, to the excellent quality of Mr. Middlemiss's long record of published results; but only those of us who have been his colleagues in India can form a sufficient appreciation of his perfect freedom from personal ambition and his disinterested devotion to the science of geology.

By reason of a combination of chances such as often affects a service which is partly official and partly scientific, I have had the peculiar opportunity of discovering the fine personal qualities of Mr. Middlemiss from two distinct

points of view; for I have had the pleasurable privilege of working directly under him in the field, and have had the honour also of being his official chief. Having thus seen him from all sides, I can confidently assert that Mr. Middlemiss's record of good work has no seamy side. This award will be keenly appreciated by all past and present members of the Indian Geological Survey; a referendum made to that critical community would have found Mr. Middlemiss returned unopposed.

The choice of the Lyell Medal is especially appropriate, as the chance possession in his youth of a copy of the *Student's Elements* was, as we in India know, the work which turned Mr. Middlemiss to the study of geology.

In writing from India to express his appreciation of the award now made by the Council, Mr. Middlemiss states with obvious sincerity that

"Much of the pleasure that I have derived from my geological work in this country has been enhanced by the friendly and helpful relations that have always existed between myself and my colleagues, who, I know, rejoice with me in the award".

The President then presented the Balance of the Proceeds of the Wollaston Donation Fund to Mr. Richard Bullen Newton, F.G.S., addressing him in the following words:—

Mr. NEWTON,—After some years in the Palæontological Department of the Geological Survey, you were transferred in 1880 to the Geological Department of the British Museum (Natural History). During this long service in two public departments not only has your work been distinguished by care and thoroughness, but you have utilized your opportunities for making yourself well acquainted with the Gasteropoda and Lamellibranchiata, more especially of the younger geological formations. The contributions which you have thus been able to make to the palæontology of parts of Africa and Asia, in addition to your work in the British Isles, have enriched the pages of our Journal for many years. On behalf of the Council, I beg to hand you the Balance of the Proceeds of the Wollaston Fund.

In presenting the Balance of the Proceeds of the Murchison Geological Fund to Mr. Frederick Nairn Haward, the President addressed him as follows:—

Mr. HAWARD,—At a time when enthusiasm in the pursuit of proofs of human workmanship on flints has threatened to outrun discretion, you have engaged in a study of the various forms of fracture which can result from natural causes, in order to demonstrate that much of the chipping attributed by some observers to Man may have been due to natural agencies. Your minute and unbiassed investigations cannot fail to exercise a useful influence on the treatment of this speculative subject. In handing to you the Murchison Geological Fund, awarded to you by the Council of this Society, I express the hope that you will regard it as a mark of appreciation of what you have already done and as an encouragement to continue your researches.

The President then handed a Moiety of the Proceeds of the Lyell Geological Fund, awarded to the Rev. Walter Howchin, F.G.S., to Professor W. W. Watts, F.R.S., for transmission to the recipient, addressing him as follows:—

Professor WATTS,—Before leaving this country, upwards of twenty years ago, Mr. Howchin had already done useful work on the Carboniferous Foraminifera. On his arrival in Australia, he continued his studies on these organisms in the Tertiary, Cretaceous, and Permo-Carboniferous rocks. It was during the prosecution of his researches among the Permo-Carboniferous glacial deposits that he came upon widespread 'tillites' at an horizon lower than that of the *Olenellus* and *Salterella* beds of the Lower Cambrian. The glacial phenomena presented by these rocks were first described in detail in a convincing paper laid by him before this Society in 1908, although a preliminary note on their existence had been read before the Royal Society of South Australia in 1901.

In addition to his researches upon these extraordinarily interesting episodes in Palæozoic times, Mr. Howchin has done much to elucidate the complicated structure of Mount Lofty, and the general physiography of South Australia. In making the award, which I now beg you to forward to him, the Council desire to testify their sense of the great importance to geological science of the work that he has done in far-distant Australia.

In presenting the other Moiety of the Proceeds of the Lyell Geological Fund to Mr. John Postlethwaite, F.G.S., the President addressed him in the following words:—

Mr. POSTLETHWAITE,—For more than forty years your name has been associated with the geology of the Lake District, for it was in 1874 that you read a paper at Keswick on the Mines and Minerals, which was destined to develop into the useful and beautifully illustrated book reissued in third edition only last year. Though minerals and ores have claimed much of your attention, the igneous rocks with which they are so often associated have been studied in the field and described by you in the pages of our Quarterly Journal. To you also is due the credit of having helped to clear away the obscurity attaching to the age of the Skiddaw Slates by your indefatigable and successful search for fossils.

The award, which it is my privilege to hand to you, has been allotted to you by the Council in testimony of their appreciation of your work in the classic ground of the English Lake District.

The President thereafter proceeded to read his Anniversary Address, giving Obituary Notices of several Foreign Members, Foreign Correspondents, and Fellows deceased since the last Annual Meeting, including Professor H. Rosenbusch (elected a Foreign Member in 1890); Professor Anton Fritsch (el. 1897); Professor H. Credner (el. 1898); F. N. Chernyshev (el. 1909); Professor A. Baltzer (el. 1911); Professor I. Cocchi (elected a Foreign Correspondent in 1874); Lord Avebury (elected a Fellow in 1855); Professor J. Milne (el. 1873); H. B. Woodward (el. 1868); Dr. T. Anderson (el. 1890); Lord Strathcona (el. 1885); J. McMurtrie (el. 1873); Dr. H. F. Parsons (el. 1877); J. L. Lobley (el. 1865); Sir James Lamont (el. 1859); W. H. Sutcliffe (el. 1903); Dr. P. L. Sclater (el. 1878); F. J. Mitchell (el. 1859); H. K. Slater (el. 1902); and T. H. Cope (el. 1905).

As the main subject of his Address, the President referred to that part of the work of George Darwin and Wallace which bore on the history and age of the Earth, and commented on the vagueness of the evidence on which estimates of the rapidity of denudation in past times are founded. The problem of denudation was beset with difficulties, due to our imperfect knowledge of the distribution of different types of rocks and climates in primæval land-surfaces. Before attempting estimates of primæval time, it should be shown that some degree of precision is attainable in calculating the amount of denudation effected in post-Glacial times and the time required to effect it.

It was now generally possible to distinguish the features in the landscape which were due to post-Glacial erosion. River-gorges, dissected plateaus, fans and deltas of gravel were presented for consideration. In some there seemed to be a possibility of estimating the bulk of the material which had to be moved and the rapidity with which the transporting agents are working.

As an example, the gorge of the River Alyn in Denbighshire was quoted. The post-Glacial excavation was of measurable size, and its contents had been shot on to a plain in the form of a fan of measurable extent. Fans spread on the flat bottoms of valleys by tributary streams, or deltas formed in lakes, were of common occurrence. In all cases it would be of value to determine a relation between three factors, namely, the size of the fan or delta, the discharge of the stream, and the character of the ground from which the material was derived. In one case, in the Vale of Neath, the stream was carried over a railway on an aqueduct, and the amount added annually by it to the fan could be observed in its passage.

Lakes occupying hollows among Drift-mounds gave a different problem. The material accumulating in them was blown and washed by rain from the surrounding slopes.

Dammed-up rivers gave opportunities for observing the amount of material transported by rolling. Canalized rivers were not paralysed as denuding agents, but asserted themselves in time of flood. The amounts dredged at various points on the canalized channel should give an accurate measure of the activities of the river.

The distance over which rivers were now transporting material should be ascertainable by observing the composition of recent alluvial deposits. Few rolled gravel directly into the sea, for the gradients in the lower parts of their courses were too low for transportation and favoured deposition. A diagram of the Exe, Medway, and Severn, showing their gradients from source to mouth, illustrated this and brought to light interesting differences. The last two had long tidal reaches and perfectly-graded middle reaches, with sharp upturns to the source which were common to all rivers. The Exe had a comparatively short tidal reach and a more steeply and less perfectly-graded middle reach. A change in the gradient was observable where the Exe passed from Devonian rocks on to Culm Measures.

An investigation on English rivers had been proceeding for some years with the object of ascertaining (1) the discharge, (2) the suspended and dissolved impurities, (3) the rainfall, (4) the areas of the basins, and (5) the character of the rocks.

The rivers suitable for the investigation were limited to those with a single definite mouth. Fen-rivers had a number of outlets, and could not be gauged. The Exe, Medway, and Severn were selected as examples of an upland stream and of canalized lowland rivers. It was sought to establish a definite relation between the level of the water on the one hand and the velocity of the current and the amount of suspended or dissolved matter on the other hand. The results were partly in accordance with anticipation. The suspended matter was scarcely measurable until the water reached a certain level above normal, but increased rapidly for higher levels. The dissolved matter was at its maximum when the river was lowest and diminished as the level rose.

The amount of material now being rolled by the Exe was determined from records of dredgings. Rainfall was dealt with by the British Rainfall Organization, as also the methods of eliminating

the error in calculating average rainfall, due to the preponderance of rain-gauges in the lower ground.

The determination of water-partings was discussed, and examples quoted where precision is not attainable.

It was concluded that, although in this country a hydrographic survey, including all the heads of this inquiry, may not be essential on the ground of utility, yet more systematic observations on the work of denudation as now proceeding are within the reach of geologists.

The ballot for the Officers and Council was taken, and the following were declared duly elected for the ensuing year :—

OFFICERS: *President:* Arthur Smith Woodward, LL.D., F.R.S. *Vice-Presidents:* Henry Howe Bemrose, J.P., Sc.D.; William Hill; Clement Reid, F.R.S., F.L.S.; and Aubrey Strahan, Sc.D., LL.D., F.R.S. *Secretaries:* Herbert Henry Thomas, Sc.D., B.Sc., and Herbert Lapworth, D.Sc., M.Inst.C.E. *Foreign Secretary:* Sir Archibald Geikie, O.M., K.C.B., D.C.L., LL.D., Sc.D., F.R.S. *Treasurer:* Bedford McNeill, Assoc. R.S.M.

The other Members of COUNCIL elected were: Professor Thomas George Bonney, Sc.D., LL.D., F.R.S.; Charles Gilbert Cullis, D.Sc.; R. Mountford Deeley, M.Inst.C.E.; James Vincent Elsden, D.Sc.; John William Evans, D.Sc., LL.B.; Professor William George Fearnsides, M.A.; Walcot Gibson, D.Sc.; Professor Owen Thomas Jones, M.A., D.Sc.; Horace W. Monckton, Treas.L.S.; Edwin Tulley Newton, F.R.S.; Professor William Johnson Sollas, M.A., Sc.D., LL.D., F.R.S.; William Whitaker, B.A., F.R.S.; the Rev. Henry Hoyte Winwood, M.A.

II.—Mineralogical Society.

January 27.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

T. Crook: The Genetic Classification of Rocks and Ore-deposits. The general principles of the classification of rocks were considered, the term rock including all mineral deposits. The exact nature of genetic grouping was defined. Both rocks and ore-deposits fall into broad natural divisions in accordance with a geological grouping of formative agents and processes, the type being determined by the last operative agent or process that gave the rock its individuality. The two main groups are (1) endogenetic deposits, arising from internal causes, and (2) exogenetic deposits, of superficial origin, and these are subdivided in a consistent genetic manner. 'Sedimentary' and 'metamorphic' products cannot be regarded as constituting two independent subdivisions. An historical review of the application of genetic-geological principles to the classification of rocks and ore-deposits was included.—Professor A. F. Rogers: Lawsonite from the Central Coast Ranges of California. Crystals from new localities were described; prismatic and tabular in habit and usually small, they displayed the forms 010, 001, 011, 110.—A. F. Hallimond: Uniaxial Augite from Mull. The small, lath-shaped crystals, which seldom exceed $\frac{1}{2}$ mm. in diameter, have refractive indices o 1·714, e 1·744, specific gravity 3·44, pronounced dichroism (o smoky-brown, e pale-yellow), two cleavage directions nearly at right angles, and an extinction angle of $30\frac{1}{2}°$ on the cleavage. A chemical analysis revealed distinct differences from ordinary diopside, and the composition approximates to that of hypersthene.—H. H. Thomas and W. Campbell Smith: Apparatus for Grinding Crystal Plates and Prisms. A gun-metal cylinder with its axis normal to a triangular brass-plate, about

5 cm. in diameter, resting on three screws, one of which has a graduated head, is movable vertically along, and rotatable about its axis, and by rotation of the graduated screw the axis of the cylinder is inclined at a known angle to the grinding lap. A crystal suitably mounted is brought by means of these two rotations into any desired position, a series of chucks of different inclinations being provided for holding it. The zero position is determined optically. A graphical method of determining the requisite rotations was described.

CORRESPONDENCE.

THE NATURE AND ORIGIN OF FIORDS.

Sir,—Although Professor J. W. Gregory denies the presence of fiords in South Victoria Land in his recently published work with the above title, I feel bound to point out that *fiord-valleys* whose characteristics agree in all essentials with his fiord-valleys (pp. 17 and 19) occur, if somewhat infrequently.

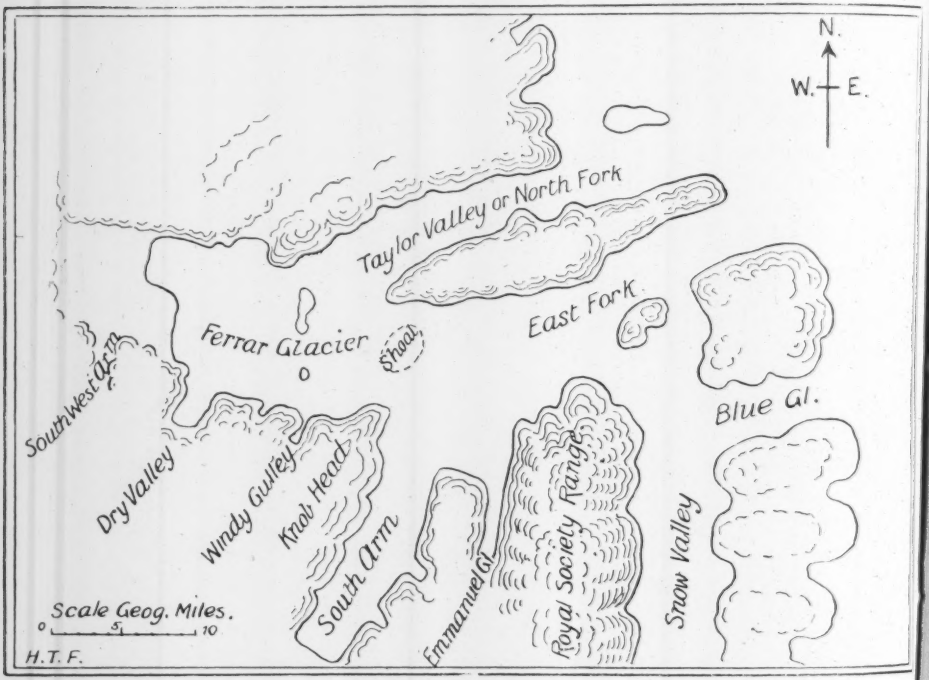
The existence of fiord-valleys on this coast strengthens rather than weakens his main theme, and, as we are led to expect (p. 479), a simple foundering, such as that which has taken place in South Victoria Land, would not form a full fiord-system. In singling out only two of the many 'inlets' which indent the coast he implies (p. 370) that they are not even simple fiords. The first, Tucker Inlet, has had only its entrance fixed by ships passing along the coast, and therefore it is not likely that any branches or arms, if such exist, would be indicated on the published maps; the second, Granite Harbour, lately surveyed in detail by Mr. Debenham of Scott's ill-fated expedition, in many respects would resemble a fiord were the sea to encroach 1,000 feet or so upon the land. Likewise the Ferrar Glacier and its branches, if depressed some 3,000 feet, would provide all the essential characteristics of a fiord (pp. 66 and 385), and the accompanying sketch-map is intended to depict the coastlines subsequent to such a submergence of the valley (see p. 190).

The points outlined above should have an important bearing on the subject of glacial erosion, i.e. the erosive power of water-substance in its solid form (ice), which once again is under discussion. Professor T. W. E. David and Mr. Priestley, after boldly showing on a map (Eleventh International Geological Congress) a network of faults determining the main tectonic features of South Victoria Land, have joined the ranks of the 'Erosionists'. (I noticed that only one of the series of east and west series of faults was made to coincide with an important east and west valley.) So too has Mr. Griffith Taylor in his contribution to the narrative of "Scott's Last Expedition"; but he does not explain why the glaciers which gouged out the valleys leading into Granite Harbour did not remove Mount Suess, nor why the ice-stream which excavated Taylor Valley (the North Fork of the *Discovery* and *Nimrod* maps) did not remove the two projecting Riegeln.

During my traverse of the then unexplored Ferrar Glacier, I, like Professor Gregory (Preface), "found it difficult to determine which

features were due to denudation, glacial and preglacial, and which were due to valley formation by movements of the earth's crust," and hence in my report described what I saw, but made no deductions. Now that I have gained further knowledge and experience I feel that I can take up a definite position. I hold that the great transverse valleys of Central South Victoria Land were not entrenched by glacial erosion, but are disruption clefts due to the unequal foundering of the land, the Royal Society Range having stood firm as the surrounding continent subsided.

I would go even a step further than Professor Gregory in denying the erosive power of ice as such. In the first place I agree with



Sketch-map showing shore-lines of Ferrar Glacier and its branches after a submergence of 3,000 feet.

Professor Garwood and Dr. Harker that the *corroding* action of a partially buoyed up glacier snout, which is thawing above water and melting below, is small. In the second place I do not see how *corrosion* by pot-holing (p. 407), the evidence for which is meagre, can deepen a valley indefinitely, for unless the water of the supraglacial cascade escapes as a subglacial stream *below the bed level of the valley* a pool will be created and the water in it will form a cushion, and so set a limit to the process. In the third case spur-truncation seems to me to be brought about by the action of running water more than by the rasping action of rock-charged ice. Between glacier side and

valley wall a racing stream is usually to be seen, which erodes both ice and rock. The stream cannot meander away from the valley-wall, for owing to the movement of the glacier the ice is renewed as fast as or faster than it disappears, while the spurs of the hills are open to the continuous attack of the water thus trained against them. No doubt this enhanced action of the water has given rise to the seemingly contradictory conclusion (p. 431) "that glaciers have the power of cutting back spurs which is greater than that of water".

H. T. Ferrar,
Geologist to the *Discovery* Antarctic Expedition.

February 23, 1914.

OBITUARY.

SIR JOHN MURRAY, K.C.B., F.R.S., LL.D., D.Sc., Ph.D.

Born March 3, 1841. Died March 16, 1914.

A feeling of profound regret was shared by all naturalists and men of science generally at the announcement on March 17 of the sudden death by a motor accident of Sir John Murray, whose name is so intimately associated with the famous *Challenger* explorations, and to whose untiring energy and devotion we are indebted for the carrying out of the results of the work, a task which, owing to the illness of Sir Wyville Thomson, fell almost entirely to Sir John Murray. The *Challenger* sailed in December, 1872, and returned in May, 1876, bringing back innumerable pelagic and other organisms new to science. Writers of eminence in the several departments were engaged, whose labours occupied from 1880 to 1895, resulting in the production of fifty large quarto volumes admirably illustrated by maps, plates, and text-figures. This fine series of "*Challenger* Reports", thanks to the efforts of Sir John Murray and the generosity of the British Government, may now be seen and consulted in all the principal libraries and scientific institutions of the world.

Born at Coburg, Ontario, Canada (March 3, 1841), John Murray was the second son of Robert Murray and his wife Isabel, daughter of the late Thomas Henderson, ship-owner. He was educated at a public school in Canada, then in 1858 at the High School of Stirling, Scotland, and later at Edinburgh University, where he came under the influence of Lord Kelvin, Clerk Maxwell, and Professor Tait.

Sir John Murray, in addition to his administrative and editorial duties, took an active part in the "*Challenger* Reports", and contributed two large volumes summarizing the scientific results of the expedition, which occupied twenty-three years of his life. Nor was Sir John Murray's work confined to the famous *Challenger* expedition, for in 1880 and 1882 he took part in the exploration of the Faröe Channel in H.M.S. *Knight Errant* and H.M.S. *Triton*. He also established marine laboratories on the shores of the Forth at Granton and on the Clyde at Millport, Cumbrae. With his steam yacht *Medusa*, fitted with all suitable appliances, he made soundings and exploration of numberless locks and straits on the coast of Scotland. (See also his and Mr. Pullar's Bathymetrical Survey of the Scottish Freshwater Locks, 6 vols., 8vo, Edinburgh, 1910.)

In addition to his writings on the *Challenger*, Sir John Murray published in *The Depths of the Ocean* valuable contributions on oceanic life in its relation to geology; the condition of our planet in past ages; on the origin of coral reefs; on geography, oceanography, and marine biology. Sir John Murray married, in 1889, Isabel, only daughter of the late Mr. Thomas Henderson, ship-owner, of Glasgow. He leaves two sons and three daughters.

He was made a Knight of the Prussian Order pour le Mérite in 1898. He received numerous medals, and was an honorary member of a great number of British and foreign scientific societies.

JAMES McMURTRIE, F.G.S.

BORN 1840. DIED FEBRUARY, 1914.

WE regret to record the death of another excellent geologist, and valued friend, Mr. James McMurtrie, F.G.S., of 5 Belvedere Road, Durdham Park, Bristol, who passed away on February 2, in his 74th year.

Mr. McMurtrie was for forty years connected with the estates of the Waldegrave family, and was manager of their collieries at Radstock until 1902. It was from this coal-field that many of the ferns figured by Brongniart in his *Histoire des Végétaux Fossiles*, 4to, 1828, were obtained.

Mr. McMurtrie was elected a Fellow of the Geological Society of London in 1873. He was a typical Scotchman and served as President of the Bristol Caledonian Society in 1906.

Born at Dalquahrran, in the parish of Dalry, Ayrshire, McMurtrie began life under his father, who was manager of the collieries at that place. He entered for a short time upon commercial life in Liverpool, but soon removed to Newcastle-on-Tyne, becoming a mining pupil at the Towneley Collieries at Ryton, where he was articled to Mr. Robert Simpson. Having completed his articles McMurtrie (in 1862) at the age of 22 went to Radstock, Somerset. During his forty years' residence he carefully studied and mapped the coal-seams of that difficult area and collected some very fine and characteristic coal-plants which he subsequently presented to the Geological Department of the British Museum, Natural History, Cromwell Road, London.

HENRY POTONIÉ.

BORN NOVEMBER 16, 1857. DIED OCTOBER 28, 1913.

WE regret to record the death of this distinguished palæobotanist. Born in Berlin he was educated in that city and in Paris, and at the age of 21 gave special attention to the study of botany. In 1880 he was appointed an assistant in the Botanic Garden at Berlin; five years later he became Palæobotanist to the Geological Survey of Prussia; in 1891 he was appointed Professor of Palæobotany in the School of Mines, and in 1901 occupied a similar post in the University at Berlin. His *Lehrbuch der Pflanzenpaläontologie* was published during the years 1897–9, and a second edition was in preparation. He was author also of other books on recent and fossil botany, and of many important papers on fossil plants.

Herring, photo. London Stereoscopic Co.

STEGANOBLASTUS.